



A RATIONAL APPROACH TO STEEL DECK CORROSION PROTECTION

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Recently, there has been a heightened interest by roofing contractors and engineers on the subject of corrosion protection for steel decks. This interest is evidenced by the numerous articles and bulletins on the subject that have been published.

Although the subject has been of recent interest to some, the issue of deck corrosion protection has been considered by the Steel Deck Institute since it was organized in 1939. Since 1939, the Steel Deck Institute has provided uniform industry standards for the engineering, design, manufacture, and field usage of steel decks. The SDI is involved with cold-formed steel products with various configurations distinctive to individual manufacturers, used to support finished roofing material or serving as a permanent form and/or positive reinforcement for concrete floor slabs.

Continuing SDI functions include the development of steel decks that are engineered for structural soundness, that maintain consistent quality, that adapt to a wide range of designs and systems, and that are economical **in both initial and life-cycle costs**. Value is determined by combining initial cost, life-cycle costs, and overall performance. Steel deck assemblies are the best value in roofing designs, combining low cost with top performance.

The Steel Deck Institute's philosophical approach to deck design is that a design professional will review the application of the information presented in the Steel Deck Institute Design Manual. The series of design manuals developed since 1939 have proven successful in their approach to steel deck design and corrosion protection. Millions of square feet of deck are placed in service annually with satisfactory performance extending back more than half a century.

The SDI Design Manual addresses corrosion protection for typical building environments, and has regularly updated its Design Manuals to assist design engineers when dealing with such problems. The information available allows the designer to specify deck types and finishes suitable to the designed project.

For current SDI Recommended Standard Definitions and Practices (excerpts from the SDI Design Manual and Construction Manual), see Appendix A.¹

Philip Levine, was Executive Vice President of Roll Form Products, Division of RFP, Inc. He served as President of the Steel Deck Institute from May 1992 until January of 1993. He was an active member of the AISC Committee on Fabrication Operations and Standards. Philip Levine died in December of 1994.

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Development of Corrosion Protection for Steel Deck

A review of past practices, standards, and observations will provide an understanding of the Steel Deck Institute's present rational approach to corrosion protection.

In 1940, the American Iron and Steel Institute conducted a survey of buildings with light steel structural systems fabricated with one shop coat of paint for corrosion protection. "Light steel structural members" was defined as "members formed from flat rolled steel, usually about 16 or 18 gage." The ribbed roof deck, however, was made of lighter gages.

The purpose of the survey was to determine the durability of the light steel with a shop coat of paint for protection, as it was not standard practice to require painting of the light steel after erection. The buildings surveyed had been in use up to 35 years. The average length of service use was from 16 to 20 years.

The prime reason given for the survey was that a study of actual service conditions would be more enlightening than any laboratory test.

On August 6, 1942, the Pittsburgh Testing Laboratory reported the results of the survey in a letter entitled, "Summary and Conclusions of Inspection Survey of Lightweight Types of Steel Construction."

The letter clearly indicates that a shop coat of paint provided an adequate corrosion protection for steel not exposed to the weather. Excerpts from the letter are as follows:

"1. Painted light steel structural members in fifty buildings distributed over the United States from coast to coast and from the Great Lakes to the Gulf of Mexico, were examined by the Pittsburgh Testing Laboratory inspectors, the investigation being limited to steel enclosed in the buildings and not directly exposed to the weather.

"10. The results of the examination herein reported appear to justify the conclusion that the commercial protective paint coatings applied to light steel structural members of the types included in this survey provide effective protection to the steel during actual service and that such light steel structural members may be expected to retain their structural properties during the life of a building when enclosed within the confines of a building and not exposed to the weather or to unusually severe conditions such as chemical fumes or to continuous contact with water."²

The development which had the most significant impact on corrosion protection and the wide use of prime coated roof deck was the introduction of the continuous coil coater. Prior to the wide use of coil coating to paint material for steel deck, galvanized steel was

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extensively used. In 1940, over 40% of the galvanized steel that was sold in the United States was used for roof deck and siding.

By the late 1960's, coil coating of steel deck had become a common practice. Coil coating is a highly-specialized process applying various types of coatings — paints, plastic laminates, adhesives, etc. — to metal that is in coil form through a series of steps in one continuous line of action.

"Since formation of the National Coil Coaters Association in 1962, the uses of coated coil have expanded dramatically as industries found the product lower in overall cost and higher in quality. The continuous coil coating process has emerged as the fastest growing method for finishing 'sheet metal' which ranges from a thickness of about one-eighth of an inch down to thinner foils of four-thousandths of an inch or less. In addition to savings and quality, the coil coating process offers the versatility of applying a primer and finish coat on one or both sides of the metal, embossing or printing the coating or applying a strippable film in a continuous process."³

In 1961, the Metal Roof Deck Technical Institute, now known as the Steel Deck Institute, stated in its "Basic Design Specification" under Protection:

"All steel roof deck shall be free of oil, grease and dirt and given a shop coat of priming paint or metal, to protect the steel deck during shipment."⁴

The statement is straight-forward and clearly states that the only purpose of the shop coat of priming paint or "metal" was to protect the steel deck during shipment. There is no mention of a galvanize ASTM classification, only the term "metal." The term "metal" was intended to be a wiped coat* of zinc, which was used for the same purpose as the priming paint; i.e., temporary protection during shipment.

By the late 1970's, three to four million tons of coated coil were produced annually.

"Translating tons to surface area, four million tons is the equivalent of 13 billion square feet or a 10-foot wide strip of metal stretching from the earth to the moon."³

The change from the use of the majority of steel for roofs from galvanize to prime painted resulted in lowering costs and providing an appropriate protective coating for most structures.

The 1971 Steel Deck Institute "Suggested Architectural Roof Deck Specification" under

* ("Wiped coat" is defined as a hot-dip, zinc-coated product that is wiped after the strip emerges from the zinc pot to produce a fully alloyed zinc-iron coating.)

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Finish is substantially the same as the one published in 1961. The 1971 statement reads as follows:

“Roof deck shall receive one prime coat of manufacturer’s standard paint, or shall be zinc-coated.”⁵

“Zinc-coated” does not refer to an ASTM specification, and therefore can be assumed to mean any amount of zinc applied to the sheet. The terms “galvanize,” “zinc-coating,” and “metal” were used interchangeably.

More often than not, a wiped coat of zinc was considered to be in compliance with these requirements. The galvanized sheet that was replaced by prime painted deck in the United States was a wiped alloyed.

The quantity of zinc on the sheet was extremely light with a total coating weight on both sides ranging from 0 up to 0.25 oz./SF. This range is in contrast to the galvanized sheet referred to today by the SDI, which has coatings weights as shown in the ASTM A525 table reproduced below. Prime coated painted steel was never, and is not now, a substitute for ASTM A525 G-60 or G-90 finishes.

The importance of the amount of zinc on the steel is explained and emphasized in the ASTM A525 Specification, Note 2:

“NOTE 2 - As it is an established fact that the atmospheric corrosion resistance of mill galvanized sheet products is a direct function of coating weight (thickness), the selection of lighter coating designations will result in almost linearly reduced corrosion performance of the zinc coating. For example, the heavier galvanized coatings perform adequately in bold atmospheric exposure whereas the lighter weight coatings are often further coated with paint or a similar barrier coating for increased corrosion resistance. Because of this relationship, products carrying the statement “meets ASTM A525 requirements” should also specify the particular coating weight designation.”⁶ (Copyright ASTM. Reprinted with permission.)

A job specification requiring galvanized coatings without specifying a particular weight can be misleading. The following table is reproduced from ASTM and defines the total coating weight per square foot for both surfaces of a sheet.⁶

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ASTM COATING DEFINITION (copyright ASTM, reprinted with Permission)

Type	Coating Designation	Previous Coating Class	Minimum Check Limit		
			Triple Spot Test oz/ft ²		Single Spot Test oz/ft ²
			Total Both Sides	Total One Side	Total Both Sides
Zinc	G 360	...	3.60	1.28	3.20
	G 300	...	3.00	1.04	2.60
	G 235	2.75	2.35	.80	2.00
	G 210	2.50	2.10	.72	1.80
	G 185	2.25	1.85	.64	1.60
	G 165	2.00	1.65	.56	1.40
	G 140	1.75	1.40	.48	1.20
	G 115	1.50	1.15	.40	1.00
	G 90	1.25 Comm.	0.90	.32	0.80
	G 60	Light Comm.	0.60	.20	0.50
	Zinc-iron alloy	G 40	...	0.40	.10
G 01		...	no minimum	...	no minimum
A 60		...	0.60	.20	0.50
A 40		...	0.40	.12	0.30
A 25		...	0.25	.08	0.20
A 01		...	no minimum	...	no minimum

Figure 1

Editors Note: In 1994 ASTM replaced A525 and A446 with one specification, ASTM A653, "Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron alloy-coated (Galvanealed) by the Hot-Dip Process." The table reproduced in Figure 1 also exists in the new specification A653. One of the significant changes is that A653 now uses the yield point of the steel as part of the classification; i.e. grade 50 means 50 ksi (minimum) yield steel.]

In the 1960's the primary protection concern was that the deck be protected during shipping. By 1969, however, new concerns were raised regarding deck storage on the construction site. Deck was often stored for indefinite periods on the job site, exposed to the elements, resulting in some rust or stain, particularly at the uncoated panel edges.

In most cases, when one coat of manufacturer's prime paint is specified, it must be assumed that some rusting will occur if the product is exposed to moisture. The extent of the rusting is dependent on the length of time that the deck is exposed to the elements. As none of the edges are painted, rusting will normally first occur on the edges of the deck. Bundles left exposed to the weather will show rust staining, not necessarily rusting, on the painted surface. However, light rust is not detrimental. The American Society of Civil Engineers states in its Specifications for the Design and Construction of Composite Slab and Commentary (ASCE, October, 1979, reprinted with permission).

*"Light rust (tight rust), such as may occur prior to installation, generally will not affect the structural integrity or performance of the deck. This light rust is acceptable in normal applications where the deck will not be subjected to a corrosive environment or continued rusting after installation."*⁷

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The result of a need for a Site Storage provision was the addition to the 1969 SDI Design Manual which reads as follows:

“Steel decking is generally supplied with a prime coat of paint which is not intended to assure protection for extended periods of time when exposed to the elements. Steel decking should be stored off the ground with one end elevated to provide drainage and should be protected from the elements with a waterproof covering.”⁸

It is interesting to note that at that time, steel decking generally was supplied with a prime coat of paint, and the only concern for the prime coat of paint was that the deck should not be exposed to the elements for an extended period.

In 1971, the wide acceptance of prime painted deck and the successful use of the prime painted deck throughout the industry was the justification for the following paragraph which appeared in the 1971 SDI Design Manual.

“Any product, used in such large quantities over a long period of time, must, in accordance with business principles, be economically sound, durable, and superior in performance.”⁵

The prime coat of paint which was intended to protect the steel during shipment was often used as a finish coat of paint, or in other words, left architecturally exposed in the structure with no further treatment. Thus one could take advantage of an unintended savings by using the prime coat of paint for a finish coat. The problem was, as stated above, that often the prime coat of paint would be left exposed in bundles on the job site, and the expected discoloration of the prime coat would take place, causing rust and rust staining. Due to the aesthetics, a dispute could ensue, as the unrealistic expectation that the prime coat could serve as an interior finish coat was not realized. The dispute was unrelated to structural corrosion, but was related to the appearance of the deck. As a result, Paragraph F, Protection, in the 1971 Steel Deck Institute Design Manual was revised in 1974 to read as follows:

“All steel roof deck shall be free of oil, grease and dirt, and given a shop coat of priming paint or metal. This prime coat is intended to protect the steel for only a short period of exposure in ordinary atmospheric conditions and must be considered an impermanent and provisional coating.”¹¹

This revised language adopted the position of the American Institute of Steel Construction in regard to prime paint. The American Institute of Steel Construction Code of Standard Practice states:

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Shop Painting: The shop coat of paint is the prime coat of the protective system. It protects the steel for only a short period of exposure in ordinary atmospheric conditions, and is considered a temporary and provisional coating.⁹

The 1974 language in the SDI paragraph on Protection, defined the environment in which prime painted deck was expected to function in the statement “the prime coat of paint is intended to protect the steel for only a short period of exposure in ordinary atmospheric conditions.” The paragraph further cautioned that the prime coat was impermanent and a provisional coating, which meant that it should not be treated as a permanent interior final coat of paint.

The latest American Society for Testing and Materials Specification, E936, Paragraph 6.2.6, Protection, states,

“All steel to be used for roof deck should be free of oil, grease and dirt and should be galvanized, coil coated, aluminum coated, or given a shop coat of primer paint. The primer coat is intended to protect the steel for only a short period of exposure in ordinary atmospheric conditions and should be considered an impermanent and provision coating. See 9.1 for Compatibility of Adhesives with Steel Deck.¹⁰ (Copyright ASTM. Reprinted with permission.)

The ASTM paragraph is in concert with the language of the American Institute of Steel Construction and the Steel Deck Institute. It is most important to understand that the cautionary note is related to atmospheric conditions and not the condition in a completed building.

Much of the construction industry continued to ignore provisions that a prime coat of paint was not to be considered a finish coat. Tarpaulins were sometimes used to cover stored bundles, but the covers could lead to condensation within the bundles, particularly if the covers are plastic or “non-breathing” materials. When trapped moisture is present, a “greenhouse effect” takes place with accelerated panel staining, especially at panel edges. Thus the SDI Site Storage section was also revised in 1974 to include a ventilation provision as follows:

“Steel decking is generally supplied with a coat of paint which is not intended to assure protection for extended periods of time when exposed to the elements. Steel decking should be stored off the ground with one end elevated to provide drainage and should be protected from the elements with a waterproof covering ventilated to avoid condensation.”¹¹

The adaptation of the AISC language that the prime coat must be considered an impermanent and provisional coating in atmospheric conditions has lead to some misunderstandings, i.e., that the prime coat is not adequate for exposure to the interior

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of a building. In most cases, the prime coat is quite adequate. This misunderstanding is referred to in James W. Palmer's article on steel roof deck published in the November 1991 issue of The Construction Specifier. In his article, Mr. Palmer points out that a common mistake is the way in which roof deck finishes are specified. He avers that once the deck is covered by the roofing material, the primer coat will be sufficient. Mr. Palmer states,

*"A common mistake in steel roof deck specifications is how finishes are specified. The manufacturer's standard finish is a primer coat of paint applied over clean, bare steel. This primer coat is less expensive than galvanized coating and will serve the purpose for most projects. The primer paint is intended to provide a base for a finish coat and is not weather resistant for a long time. If the insulation and roofing are going to be applied quickly, then the primer coat will be sufficient."*¹² (The Construction Specifier, November 1991, reprinted with permission.)

In 1978, the word "metal" in the Protection paragraph of the SDI Design Manual was changed to read "galvanized or aluminized." Likewise, in the "Architects' Specification," the words "zinc coating" were changed to "galvanized or aluminized."

By 1978, galvanized decks, as well as prime coated decks, were used in more demanding environments. In structures such as industrial plants, waste treatment plants, coke and steel plants, petroleum refineries, chemical plants, pulp and paper mills, food plants, power generation facilities, specialty areas (schools, natatoriums, workshops, etc.) the bottom side of the deck required corrosive protection from the interior environment caused by the use of the building. It became apparent that a combination of galvanized, galvanized prime painted, or galvanized field painted deck were necessary. Consequently, the statement, "Steel decking is generally supplied with a prime coat of paint" was omitted from the paragraph on Site Storage in the 1978 SDI Design Manual.

In 1978, the SDI encouraged the use of painted deck by pointing out the steel deck has been in place and performing satisfactorily for half a century. In addition to providing a structural component, painted deck can perform as an exposed ceiling:

*"Although steel deck is primarily a structural component, it is a visually satisfactory ceiling under many conditions. With the properly specified factory and field coatings, steel deck is easy to maintain, durable, and aesthetically pleasing."*¹³

In 1984, a recommendation in the Commentary was added to the Design Manual that prime painted deck should be field painted, especially if it was going to be part of an architecturally-exposed ceiling. The *Commentary* further stated that in corrosive or high moisture atmospheres, such as the interior environments previously referred to, a galvanized finish of G-60 or G-90 is desirable. In highly corrosive or chemical atmospheres, no specific recommendations were made, but the user was cautioned to contact the

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manufacturer of the product. The added *Commentary* was stated as follows:

"Field painting of prime painted deck is recommended especially where the deck is exposed.

In corrosive or high moisture atmospheres, a galvanized finish is desirable in a G-60 or G-90 coating.

*In highly corrosive or chemical atmospheres, special care in specifying the finish should be used. In this case, individual manufacturers should be contacted."*¹⁴

Note: The word "exposed" is intended to mean "architecturally exposed," not exposed to the elements. The erection process can render the deck unsuitable for an architecturally exposed surface; therefore, a field coat of paint is recommended where the deck is exposed. Mr. Palmer's article states, "Field painting a roof deck that is left exposed on the interior will allow use of any fastener type and will cover up scratches or imperfections."¹²

The various changes to the *Protection*, *Site Storage*, and *Commentary* sections were made in order to keep up with new innovations of collateral building materials and new applications of the uses of steel deck.

Steel deck panels have a well-developed history of good performance and in a wide range of building environments. In 1991, however, it became apparent to members of the Steel Deck Institute that certain new collateral materials introduced in the 1980's were corrosive when in contact with steel deck. The 1984 *Commentary* was modified as follows:

*"...where reactive materials could be in contact with the steel deck, special care in specifying the finish should be used. In this case, individual manufacturers should be contacted. See ASTM C1126-89, Paragraph 11.3":*¹⁴

11.3. "Phenolic foams may contain some compounds which may promote corrosion in the presence of liquid water. As far as can be ascertained, there are currently no directly applicable ASTM corrosion tests for phenolic foams. An attempt will be made to develop a meaningful corrosion test and will be incorporated into the standard when it becomes available. When it is anticipated that the foam will be in direct contact with metal, the foam supplier shall provide the proper installation procedure."¹⁵
(Copyright ASTM. Reprinted with permission)

In 2001, a statement was added to the SDI Design Manual in the *General Information* section, in regard to fire retardant treated (FRT) plywood. The paragraph states the following:

*"Fire retardant treated plywood contains chemicals that can develop a corrosive environment when adequate moisture and heat are present. Precautionary measures should be taken by the designer to prevent such an environment when using fire retardant treated plywood with steel deck."*²²

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Summary of Background

The 1991 Steel Deck Institute "Specification Commentary for Steel Roof Deck" state:

***"5.1 Finishes:** All steel to be used for roof deck shall be galvanized, aluminized or prime painted.¹⁶*

In spite of all the cautionary notes and the intent of the deck manufacturer regarding prime coats, most prime painted decks will be installed and used without field painting. The overwhelming percentage will be successful, a testimony to the prime coat quality as well as to having been matched by the designer to the proper environment.

A common specification presently used by design specifiers of roof deck is one related to "touch-up painting" which requires that touch-up paint be blended into adjacent surfaces on the deck where those surfaces are to be exposed. The word "exposed" is interpreted as "exposed to view," not "exposed to the elements."

The SDI member companies offer a variety of finishes for steel decks. The choice of corrosion protection is an engineering decision for the building design engineer. The engineer must consider the building environment, the structural system, the deck, and types of overlayment when specifying any part of the system.

Selecting a Protective Coating

The life of any protective coating depends largely upon the corrosion condition to which it is exposed. Therefore, it is essential to define the environment in which the steel deck is to function before selecting a protective coating.

Steel deck serves multiple functions during and after construction and is subjected to two different environments, one on the top surface and one on the bottom. A list of the wide range in environmental exposures has been provided by the Steel Structural Painting Council (SSPS).¹⁷ (See Appendix B).

It is reasonable to assume that at least one side of the steel roof deck will be exposed to the same environment as the structural steel or joist, as the deck is supported by the joist or structural steel.

When structural steel and joists are painted with a prime coat and left unpainted in the field, it is assumed that they are in a 0 or 1A environment (interior, normally dry) where corrosion protection is not necessary. "Specification 14.01, Steel Joist Shop Painting System," is a system intended as a one-coat shop paint for open web and long span steel Zone 1A).

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It is the assumption of the Steel Deck Institute that a roof properly constructed and properly maintained would create an environment similar to Zone 0 or Zone 1A (interior, normally dry) where the temperature rarely falls below the dew point, where the humidity rarely exceeds 85%, where corrosive protection is not necessary, and the paint system is considered a temporary protection of the deck during delivery and erection.³

The assumption that was based on the fact that the design and the construction details of the roof will comply with the SDI Design Manual which states,¹⁸

4. Collateral Material: *Although certain collateral materials are not supplied by the steel deck manufacturer, it is the desire of the Steel Deck Institute to have certain principles followed in specifying and furnishing these collateral materials in order to provide a satisfactory deck assembly.*

4.1 Insulation: *All steel roof decks shall be covered with a material of sufficient insulating value to prevent condensation under normal occupancy conditions. Insulation shall be adequately attached to the steel roof deck by adhesives or mechanical fasteners. Insulation materials shall be protected from the elements at all times during the storage and installation.*

4.3 *A suitable roof covering shall be applied over the insulation.*

The Steel Deck Institute assumption in regard to a normal dry interior environment is in concert with the American Institute of Steel Construction, the American Society of Civil Engineering, the Steel Structures Painting Council, the Steel Joist Institute, and the Canadian Sheet Steel Building Institute.

The AISC Specification, *General Requirements*, states,

"Unless otherwise specified, steel work which will be concealed by interior building finish or will be in contact with concrete need not be painted."

"The surface condition of steel framing disclosed by the demolition of long-standing buildings has been found to be unchanged from the time of its erection, except at isolated spots where leakage may have occurred. Where such leakage is not eliminated, the presence or absence of a shop coat is of minor influence."¹⁹

The American Society of Civil Engineers states,

'Light rust (tight rust), such as may occur prior to installation, generally will not affect the structural integrity or performance of the deck. This light rust is acceptable in

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normal applications where the deck will not be subjected to a corrosive environment or continued rusting after installation.”⁷

The Steel Structural Painting Council, in its SSPC Paint System Specification, SSPC PS 14.01, “Steel Joist Shop Painting System,” states,

“This paint is intended as a one-coat shop paint for open web and long span steel joists that may be either enclosed or exposed in the interiors of buildings where the temperature rarely falls below the dew point, where the humidity rarely exceeds 85% and where corrosive protection is not necessary.”²⁰

The Steel Joist Institute Manual, Paragraph 3.3, comments on paint,

“The standard shop paint shall conform to one of the following:

A. Steel Structures Painting Council Specification 15-68T, Type 1, red oxide.”²¹

Steel Structures Painting Council's SSPC Paint Specification, SSPC Paint 15, “Steel Joist Shop Paint,” states:

“These primers are suitable for exposures in environmental zone 1A (interior, usually dry...)”²²

The Canadian Sheet Steel Building Institute indicates in its June 1991 Newsletter that its product standards have consistently called for the following:

“...a minimum zinc coating...on steel exposed to the interior environment of a building conditioned for human comfort.”²³

Galvanize vs. Paint

The Canadian Sheet Steel Building Institute at this time recommends the following in its June 1991 Newsletter:

“CSSBI product standards have consistently called for a minimum zinc coating (wiped coat, galvaneal or electrogalvanized with chromate treatment) on steel deck exposed to the interior environment of a building conditioned for human comfort.”²³

Steel deck exposed to the interior environment of a building conditioned for human comfort falls into environmental category 0 or 1A (no corrosion protection required). In those environments where no corrosion protection is required, a prime coat of paint is equally appropriate for environmental category 0 or 1A (interior, normally dry).

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Tests described by Ernest W. Horvick in the Steel Structures Painting Council publication on cold rolled steel panels clearly demonstrate that light zinc-coated steel provides no more corrosion protection than a prime coat of paint in a mildly corrosive environment. After two years and four months, the wiped light zinc electrogalvanized coating provided little or no more protection than the painted sheet. Mr. Horvick states:

"The choice of paint and of zinc coating thickness was dictated by the expected slow rate of corrosion in this environment. From the inspection date, the times to first nodular rusting of the painted panels and to five percent rusting of the unpainted panels were determined and plotted.

"At the end of 120 weeks, rusting had begun on both painted ungalvanized steel and the unpainted zinc-coated panels."²⁴

For more severe environments, the Canadian Sheet Steel Building Institute requires heavier coatings. The CSSBI statement is as follows:

"The heavier coatings (i.e. Z275 galvanized or AZ150 aluminum-zinc alloy) are recommended where the deck is exposed to more severe environment."²³

The Steel Deck Institute also requires heavier coatings for corrosive or high moisture atmospheres. The SDI provision is as follows:

"In corrosive or high moisture atmospheres, a galvanized finish is desirable in a G-60 or G-90 coating."¹⁸

It is important to understand that in some environments a galvanized coating would be no more effective for corrosion protection than would a prime painted sheet. Zinc coating, like all coatings has a finite life. For any given corrosive environment, the thickness of the coating will determine the life of the coating.

The most important factors controlling the rate at which zinc corrodes in atmospheric exposures are the duration and frequency of moisture contact, the rate at which the surface dries, and the extent of industrial pollution in the atmosphere.

The life of zinc coatings in rural districts is four to ten times that of the same coatings in industrial districts. The difference is understood easier when the process of corrosion of zinc is examined. The following illustration from a Bethlehem Steel brochure shows the time to first rust, in years, for zinc-coated sheet steel in various environments. The data show the effect of different environments on the expected life of galvanized sheet steel.²⁵ A G-60 coating can last from less than one year to 10 years, depending on the atmospheric environment. The data also show that the coating life is directly proportional to the weight of the zinc coating on the strip.

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It is important to note that the illustration deals with corrosion time in a free air atmosphere with alternate wetting and drying, and that corrosion can be dramatically accelerated if the unit does not have free access to air. Such would be the case in an insulated under-roof environment where moisture is present from leaks or high humidity.

Corrosion of zinc-coated sheet steel in various environments

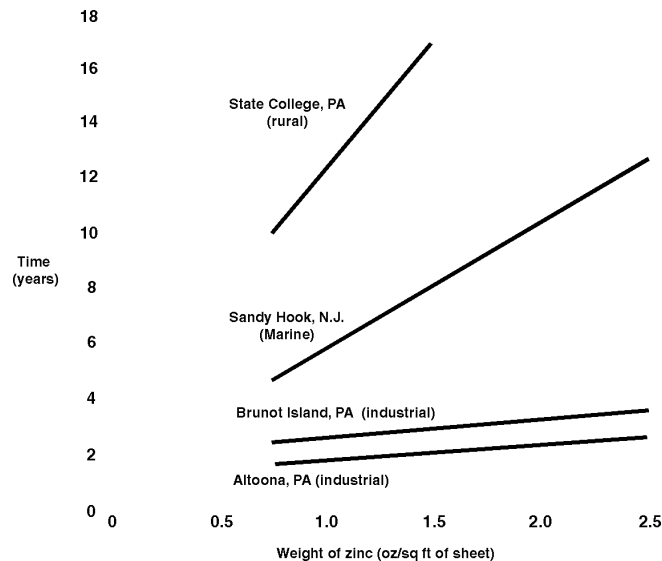


Figure 2

Hot-Dip Galvanize/"Galvalume" (Steel Sheets Coated with Hot Dip Aluminum, Zinc)

Galvalume has an excellent durability in the atmosphere, but this material may have reduced durability if it is not in an environment with free access to air.

The Bethlehem Steel October 31, 1991 "Twenty-five Year Update of the Atmospheric Corrosion Tests of Hot Dipped Coated Sheet Steel," clearly points out that the report deals solely with outdoor corrosion performance of the material. The outdoor corrosion protection of the material may not be relevant to the performance of Galvalume in an under-roof environment.²⁶

Bethlehem Steel's 1988 Technical Bulletin 206 points out the following:

"Galvalume has excellent durability in the atmosphere because of the protection, air-formed oxide that forms on the surface. However, the situation is different inside coils or in bundles of closely nested formed panels, because there is no free access to air. If water or moisture is present, a faster type of corrosion occurs due to the lack of an inhibiting oxide film. Under these conditions, storage stain on Galvalume sheet can occur in as little as 24-48 hours."²⁷

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Considering that storage stain can begin in 24-48 hours in an environment without free access to air, it is reasonable to conclude that the Galvalume may not provide as effective corrosion protection for a leaking roof with wet insulation as would be expected. The base steel will corrode from the inside out, but over a period of time after the coating is gone.

At the Eighth International Specialty Conference on Cold-Formed Steel Structures in November of 1986, it was reported that tests had been conducted on Z275 galvanized coating and AZ150 Galvalume to determine the bond properties of both coatings against concrete slab. In addition, the tests revealed the ability of galvanized coating and Galvalume to prevent corrosion caused by exposure to wet concrete. The test specimens were allowed to cure to reach full strength between 31 and 34 days before the effects of wet concrete on AZ150 Galvalume and Z275 galvanized coatings were examined. The results of the tests revealed a 50% weight loss of metallic coatings on Galvalume. In some areas, the base steel was completely exposed in both the Z275 galvanized coating and the AZ150 Galvalume, as shown in Figures 3 and 4.²⁸

Figure 3

Cross-Sectional Photomicrograph of Galvalume steel after exposure to concrete

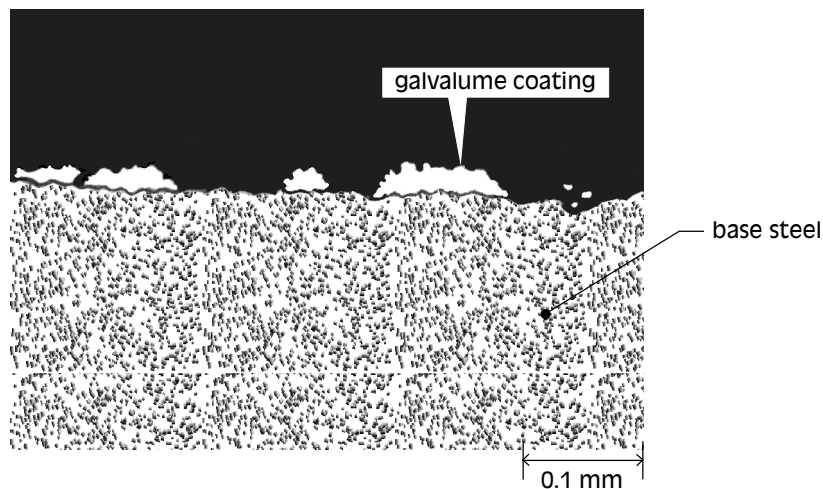
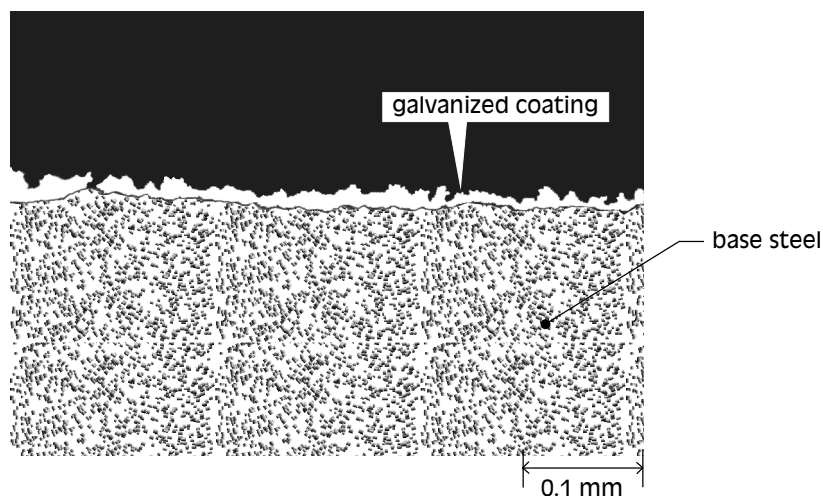


Figure 4

Cross-Sectional Photomicrograph of Galvanized steel after exposure to concrete



Editors note: Figures 3 and 4 are drawings made to illustrate the photomicrographs.

A Rational Approach to Steel Deck Corrosion Protection

It was concluded that Galvalume is an acceptable material for composite floor deck in applications where water will not penetrate the concrete to the top surface of the steel deck and chloride contamination is avoided. The advantages of Galvalume and galvanize still apply to the underside of the deck. There is minimal advantages for the top side of the deck.

The "Twenty-year Atmospheric Corrosion Testing" conducted by Bethlehem Steel Corporation in conjunction with BIEC International, Inc., concluded that Galvalume is excellent for long-term outdoor corrosion resistance, and does not suggest that this material will provide exceptional corrosion protection in an environment without free access to air.

Galvanized materials have a similar problem of accelerated corrosion if exposed to moisture in other than an environment with free access to air, as indicated by The American Society for Metals, Volume 2, 1964.

*"Zinc coatings are occasionally subject to an abnormal type of corrosion that results in bulky white corrosion products. Such corrosion originates from contact with water without free access of air. Zinc-coating material to be stored or used where "sweating" or other exposure to stagnant water may occur, can be protected to some extent by a chromate surface treatment that has been developed for this purpose."*²⁹

Bethlehem Steel cautions against a false sense of security using Galvalume or galvanized coated sheet for roof decking, as Galvalume or galvanized coatings exposed to wet insulation may corrode even if there is a slow leak. The Twenty-year Six-month Warranty for Galvalume specifically states that the Warranty does not apply when the following conditions exist:

"H. Deterioration of the panels caused by contact with green or wet lumber or wet storage stain caused by water damage or condensation.

*I. Presence of damp insulation or other corrosive materials in contact with or close proximity to the panel."*³²

There are no applicable ASTM corrosion tests for coatings exposed to wet insulation in a roof environment. One should not take the results of an atmospheric corrosion test and apply it to this condition.

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Copper Bearing Steel

A proposal has recently been made to include copper bearing steel in Section 6.2.5 of the ASTM Standard E936-89 ("Practice for Roof System Assemblies Employing Steel Deck Preformed Roof Insulation and Bituminous Built-up Roofing").³¹

Adding copper to carbon steel will be beneficial for atmospheric corrosion. As is the case with Galvalume, it would provide little or no benefit if the corrosion is caused by water from leakage or from condensation in the roof.

The U.S. Steel Group Bulletin dated November 19, 1991 explains,

*"Steel roof decks are not exposed to weathering condition, except a short time after installation, and corrosion, if it occurs, would be caused by water from leakage or from condensation. The corrosion performance of copper-bearing steel deck would be about the same as that of copper-free steel. Of course, copper-bearing steel may be used for roof deck, but it would cost more without any advantage over copper-free steel. There is no need to specify copper-bearing steel for steel roof deck."*³²

Zinc coatings with Paint Films

Traditionally, engineers have chosen between zinc coatings and paint films for corrosion protection, and it appears as if these coatings are competing approaches to steel protection market. In reality, the use of a zinc coating with a paint film is the most effective corrosive protection in corrosive environments. Tests and experience have proven the actual service to be twice that of the sum of the individual coating films.

In addition to protecting the deck from the various environments listed, many coatings are required to provide a decorative function. In many cases, the factory applied coating may have to be a good primer and be compatible with coatings applied to the finished deck.

Multiple Paint Films

There are a number of benefits in selecting multiple films. This allows a corrosion-resistant primer to be top-coated with a low-pigment color paint film. The top coat can be chosen to resist weathering or other corrosive environments without concern for its ability to adhere to the metal as long as it adheres to the prime coat. The requirements of the top coat interacting with its environment is different than the requirements of the prime coat interacting with the metal (Figure 5 below shows additional benefits).³³

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Effectiveness of multiple films in reducing water transmission to the metal surface.

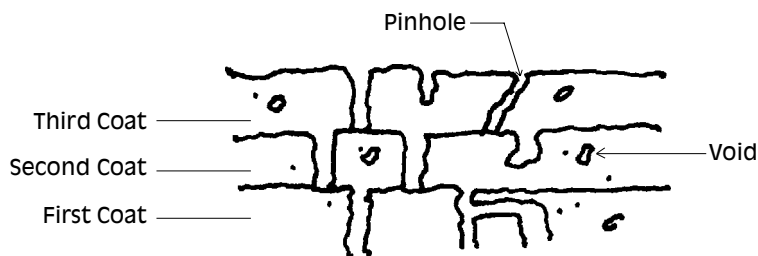


Figure 5

A symposium on Corrosion of Metals under Thermal Insulation was held in October of 1983. The sponsors of the symposium were the ASTM Committee C-16 on Thermal Insulation and G-1 on Corrosion and the National Association of Corrosion Engineers, the Institution of Corrosion Science and Technology, and the Materials Technology Institute of the Chemical Process Industries. Numerous papers on various aspects of metal corrosion under thermal insulation were presented, including protective coatings.

The primary concern was corrosion caused to carbon steel equipment due to wet insulation. None of the experts suggested that galvanized or Galvalume coatings would prevent corrosion in a wet insulation environment. On the contrary, there was a strong suggestion that zinc coatings are a poor choice, and that non-zinc paint films are a better choice.

In the article, "Factors Affecting Corrosion of Carbon Steel Under Thermal Insulation,"³⁴ Perter Lazar, III suggests that zinc coatings in any form have extremely poor performance in the wet insulation environment. He makes the statement, "Finally, many coatings depend on some form of sacrificial inhibitor or are essentially only that (for example inorganic zinc rich coatings). Zinc rich coatings have given extremely poor performance in our plants under insulation." He gives the following reasons for the poor performance:

1. *"There is the possibility of reversal in the polarity of galvanic couples, with increasing temperature.*
2. *Salts carried in and deposited with the water interfere with or destroy the effectiveness of the inhibitors.*
3. *The subinsulation environment is not freely ventilated and may not have adequate oxygen or carbon dioxide for film forming reactions to occur."*

Regardless of the type of insulation, a protective coating of paint is effective in preventing corrosion under wet thermal insulation, and is the recommended practice of William G. Ashbaugh, manager of corrosion and materials engineering for Union Carbide

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Corporation. In his article, "A Study of Corrosion of Steel Under a Variety of Thermal Insulation Materials,"³⁴ he has selected epoxy coatings as the primary line of defense for corrosion protection under the insulation.

The choice of the paint system might be determined by the selection of insulation. Although no insulation will eliminate the possibility of corrosion, some insulation types are less apt to cause problems because they are non-absorbent and chemically benign.

Selection Criteria

The selection of a deck type for a specific application depends on both structural and environmental conditions. The deck must possess both strength and durability. Environmental factors are most important and may dominate long-term performance. Other important factors must also be considered, such as cost, appearance, and design. In most cases, in the steel construction industry, one cannot afford to use the most corrosive-resistant material, and a compromise must be made for a material with the lowest combined initial cost plus maintenance costs for some defined period of time. An inexpensive material may not be available for a particular environment.

If a roof leaks, then it should be repaired. The wet insulation should be removed rather than requiring an expensive corrosion prevention material that may not be effective.

The engineer's knowledge of the environment and the behavior of collateral materials is essential. The most trustworthy criterion available is previous service use.

Both prime painted and galvanized steel deck have a record of long and successful service. When new construction materials are used, their impact on steel deck must be evaluated by the system designer.

Nothing has replaced previous service use as a rational approach to corrosion protection for deck.



A Rational Approach to Steel Deck Corrosion Protection

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Appendix A



ROOF DECKS		
Function (Environment)	Finish	Comment
Not exposed to view; dry interior, non-corrosive	One coat of primer paint	<p>All steel roof decks shall be covered with a material of sufficient insulating value to prevent condensation under normal occupancy conditions. Insulation shall be adequately attached to the steel roof deck by adhesives or mechanical fasteners. Insulation materials shall be protected from the elements at all times during the storage and insulation. (See ASTM C1126-89)</p> <p>If acoustical batts become wet, they shall be allowed to thoroughly dry without being compressed before installation.</p> <p>Any field painting or touch-up of abrasions or deterioration of the primer coat or other protective finishes shall be the responsibility of the buyer.</p>
Deck is exposed to view; dry interior, non-corrosive	Field painting of prime painted deck [Editors Note: G-30 may also be adequate.]	
In moderately corrosive or high moisture atmospheres	A galvanized finish is desirable in a G-60 or G-90 coating	
In highly corrosive or chemical atmospheres or where reactive materials could be in contact with the steel deck	In this case, individual manufacturers should be contacted	
Cellular roof decks	Minimum G-60 galvanized	
Acoustical decks	Should be either galvanized or galvanized and painted.	
Long Span Roof Decks	Field painting and touch-up may be required for decks with bottom side exposure.	
Cementitious insulating fill	Shall be poured only over galvanized deck and shall be adequately vented.	
FORM DECK		
Function (Environment)	Finish	Comment
Non-composite steel deck as a form for reinforced concrete slabs	1. Galvanized (Conforming to ASTM A525); [Editors Note: ASTM A653 has replaced A525.]	<p>The finish on the steel composite deck shall be as specified by the designer and be suitable for the environment of the structure.</p>
For any permanent load carrying function	2. Uncoated (Black); 3. Painted with a shop coat of primer paint (one or both sides)	
	A minimum galvanized coating conforming to ASTM A525, G-60 is recommended [Editors Note: ASTM A653 has replaced A525 - G30 may be acceptable.]	

COMPOSITE STEEL FLOOR DECK		
Function (Environment)	Finish	Comment
<p>Composite steel floor deck; dry interior; noncorrosive</p> <p>In areas where salt water, either brought into the structure by cars in winter or carried by the wind in coastal areas, may deteriorate the deck.</p> <p>Steel deck, raceways, trench and components</p>	<p>The finish on the steel composite deck shall be as specified by the designer and be suitable for the environment of the structure.</p> <p>Since the composite deck is the positive binding reinforcement for the slab it must be designed to last the life of the structure; a minimum recommended finish is galvanized coating conforming to ASTM A525 G-60. [Editors Note: ASTM A653 has replaced A525 - G30 may be acceptable.]</p> <p>A minimum G-90 galvanizing is recommended, and the exposed bottom surface of the deck should be protected with a durable paint. The protective measures must be maintained for the life of the building.</p> <p>The galvanized finish used on trench normally equals or exceeds that of the steel floor raceway finish</p>	<p>Phosphatized/painted deck has a bare (phosphatized top surface which is the side to be in contact with the concrete. This bare top surface can be expected to develop rust before concrete is placed. The bottom side of the deck has a primer coat of paint.</p> <p>It is well accepted that decking with light tight rust provides shear bond equivalent to galvanized decking; therefore, tested galvanized load capacities may be used for rusted * decking.</p> <p>* Concrete provides an alkaline environment that discourages corrosion. Since most applications of composite deck are in dry interior areas, field painting of burned, cut or abraded areas is not usually required</p> <p>Since the composite deck is the positive bending reinforcement for the slab, it must be designed to last the life of the structure.</p> <p>The finish shall be as specified by the designer and be suitable for the environment of the structure and in conformance to applicable standards and codes.</p> <p>If the appearance of the shop welding is objectionable at close range in the final installed condition, consideration can be given by the designer to specifying finished postweld surface treatment. Special field applied paints or embossed and textured metal surfaces may be specified.</p> <p>Note: The above paragraphs are excerpts from the Steel Deck Institute Design Manual and the SDI Manual of Construction with Steel Deck.</p>

DECK ORDERING LIST

Deck Finish

Prime Painted — Manufacturers Standard

G-60 Galvanized

G-90 Galvanized

[Editors Note: G30 may be acceptable.]

Prime Paint (Manufacturers Standard) over G-60 galvanizing

Uncoated

Other — Specify in separate document

Appendix B



Environmental Zone	Zone Conditions
0	Dry interiors where structural steel is embedded in concrete, encased in masonry, or protected by membrane or non-corrosive contact type fireproofing. Painting system suggestion: leave unpainted.
1A	Interior, normally dry (or temporary protection). Very mild. Painting suggestion: PS 18 latex and PS 7 (one coat).
1B	Exteriors, normally dry
2A	Frequently wet by fresh water. Involves condensation, splash, spray or frequent immersion.
2B	Frequently wet by salt water. Involves condensation, splash, spray or or frequent immersion.
2C	Fresh water immersion
2D	Salt water immersion
3A	Chemical exposure, acidic (pH 2.0 to 5.0)
3B	Chemical exposure, neutral (pH 5.0 to 10.0)
3C	Chemical exposure, alkaline (pH 10.0 or 12.0)
3D	Chemical exposure, presence or mild solvents, intermittent contact with aliphatic hydrocarbons (mineral spirits, lower alcohols, glycols, etc.)
3E	Chemical exposure, severe. Includes oxidizing chemicals, strong solvents, extreme pHs, or combinations of these with high temperatures.

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