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Detailing of Weathering Steel Facades

Détails des façades en acier patinable

Konstruktive Ausbildung von Fassaden aus wetterfesten Baustählen

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SUMMARY

The success of weathering steel façades depends on the selection of appropriate materials, consideration of the environmental exposure, and proper detailing of the cladding. Samples of successful installations are compared with details of failed weathering steel façades. These failures were caused by environmental exposure and improper detailing, and include glass breakage, accelerated corrosion of damp sections, and disintegration from expansion of corrosion products. Guidelines for the proper detailing of weathering steel are presented.

RÉSUMÉ

Le succès des façades en acier patinable dépend de la sélection des matériaux appropriés, de la prise en considération des conditions d'environnement et d'une grande précision dans la conception de la construction. Des exemples d'installations réussies sont comparés avec des installations où les détails montrent des défauts. Ces défauts étaient causés par les conditions d'environnement et par une mauvaise conception des détails. Le résultat de ces défauts est, par exemple, le bris des vitres, une corrosion accélérée des parties humides, et la destruction due a l'expansion des produits de la corrosion. Des exemples pour une bonne conception des constructions en acier patinable sont présentés.

ZUSAMMENFASSUNG

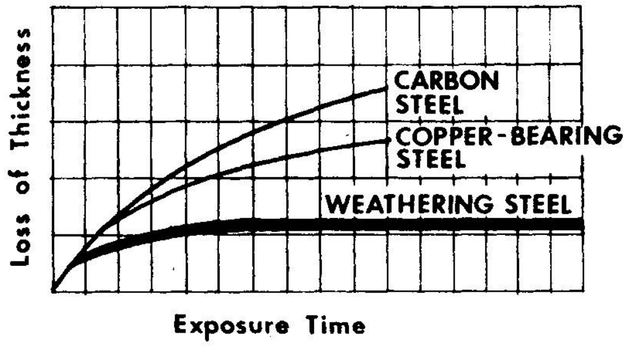
Der Erfolg von wetterfesten Stahlfassaden hängt von der Wahl des geeigneten Materials, der Berücksichtigung der Umwelteinflüsse und von der sachgemässen Wahl der konstruktiven Details ab. Beispiele erfolgreicher Ausführungen werden mit Fällen von schadhaften, wetterfesten Stahlfassaden verglichen. Diese Schäden wurden durch Umwelteinflüsse sowie durch ungeeignete Konstruktionsdetails verursacht und beinhalten Glasbruch, beschleunigte Korrosion in feuchten Bereichen und Zersetzung durch Ausbreitung der Korrosionsrückstände. Richtlinien für geeignete, konstruktive Details aus wetterfestem Stahl werden aufgezeigt.

1. INTRODUCTION

When weathering steel was first introduced to the building industry in the 1960's, it seemed to be an ideal material for bridges, structures and building facades. The steel is left unpainted, and when exposed to the atmosphere, it develops an oxide coating which inhibits further corrosion. Even though the initial cost of weathering steel was higher than plain carbon steel, the potential for substantial savings in painting and maintenance costs convinced architects and engineers to use the product. After two decades of using weathering steel, some very successful buildings have been constructed and some failures have raised serious questions about the future of the material. Architects and designers must understand the characteristics of weathering steel and follow a few guidelines in the design of weathering steel buildings in order to use the material to its fullest potential and to avoid disastrous failures.

1.1 Background

The first low-alloy steels were developed in the 1930's to meet the demand for a high-strength steel. Small amounts of chromium, nickel, copper, and other alloys were used to produce the high strength. When long-term exposure tests were conducted, it was found that these low alloy or weathering steels had four to six times the corrosion resistance of plain carbon steel.



CORROSION RESISTANCE OF WEATHERING STEEL

The initial appearance of weathering steel is similar to carbon steel, but the color and texture of the rust film which forms are very different. The rust on carbon steel is orangish brown, porous and voluminous. The rust formed on weathering steel is a thin, fine-grained film which undergoes a color change as it weathers from orange-brown to a dark brown or warm purple-black. The longer the steel is exposed, the more durable the oxide coating, or patina, becomes. For the patina to form, the steel must be exposed to alternating wet and dry cycles. In an industrial atmosphere, tests show the patina will form and the corrosion rate will decrease to insignificant levels after two to four years[1].

For many years, the primary use of weathering steel was in railroad cars, transmission towers and other industrial applications. The first major architectural use of weathering steel was in 1961 when Eero Saarinen and Associates designed the John Deere Office Building in Moline, Illinois. This seven-story structure has an exposed, unpainted exterior facade of weathering steel. The innovative use of a new material and Eero Saarinen's reputation gave the building considerable publicity. Other buildings were soon constructed with exposed weathering steel, including the Chicago Civic Center and the U. S. Steel Building in Pittsburgh.

The performance of weathering steel buildings has been inconsistent. The weathering steel on the Deere Building has performed well and the same material was chosen for an addition constructed in 1978[2]. By contrast, inappropriate detailing of other weathering steel buildings resulted in failure of the exterior facade and portions of the wall had to be removed or rebuilt. In 1980, the State of Michigan imposed a ban on the use of unpainted weathering steel for bridges after finding excessive corrosion and determining that the corrosion rate of some weathering steel was not tapering off. A later study of 49 weathering steel bridges by the American Iron and Steel Institute found that when excessive corrosion occurred it was located at areas of high chloride concentration or continuous wetting[3].

2. FACTORS AFFECTING WEATHERING STEEL PERFORMANCE

The characteristics of weathering steel must be understood in order to achieve its desired qualities and to avoid problems. The performance of weathering steel in building facades is dependent on three factors: the composition and handling of the material, the environment, and most importantly, the design and detailing of the building.

2.1 Material

The alloy composition of the steel affects its corrosion resistance and weathering characteristics. The low alloy steels with superior corrosion resistance, known as "weathering steels," are sold in the United States under the brand names "Cor-Ten" and "Mayari R" and are available from a number of steel producers worldwide. Weathering steels produced in the United States are generally specified under ASTM Standards A 242 or A 588. The standards specify the required yield strength and corrosion resistance and leave the composition of the steel up to the manufacturer. The user should consult the steel producers on the applicability of a particular steel composition and the specific brand names should be specified[4]. When in doubt about the suitability of a particular steel, exposure tests can be made at the building site. Compatible weathering steel bolts and welding electrodes should be used for unpainted connections.

The early appearance of weathering steel depends on its surface preparation and handling during construction. To achieve a uniformly weathered appearance, all exposed steel should be blast-cleaned or pickled to remove mill scale. During erection, the steel should be handled as a finish material and marks with oil, chalk, or paint should be avoided.

2.2 Environment

The development of the oxide coating on a particular weathering steel has long been recognized as depending on time, degree of exposure, and the environment. Long-term corrosion tests of weathering steels have been performed since the 1930's. The testing programs were generally designed to measure the amount of corrosion of steels of various alloy compositions. Steel samples were exposed to different environments and the rate of corrosion in terms of weight loss was measured at periodic intervals. Before a user relies on these test results, it should be verified that the environment and material used in the test are the same as those for the planned building.

On-site exposure tests were performed at some early weathering steel building sites, such as the John Deere Building. Exposure of steel samples for two or three years cannot predict the final appearance of the building, but it can reveal applications which are totally inappropriate. The effect of the environment on the corrosion is so important that some experts recommend on-site corrosion testing of weathering steels before use in any environment. Great differences in corrosivity have been found at locations only a few miles apart.

Steel producers suggest weathering steel is appropriate for most atmospheric environments: urban, suburban, rural, moderate industrial, and moderate marine. Faster weathering is promoted by moderate marine and moderate industrial environments compared to rural environments. Weathering steels are not recommended for use in severe marine environments. Soluable chloride salts present in marine environments prevent the formation of the stable, protective oxide coating. Weathering steel should not be used in industrial environments with corrosive fumes.

2.3 Design

The unique properties of weathering steel must be understood to design a successful weathering steel facade. The most important design consideration is to avoid prolonged contact of the steel with moisture. A constantly wet weathering steel surface will not form a protective patina and will corrode at an unacceptably high rate. The sources of moisture to consider are not only rain and snow, but also condensation, wet soil or moist plants, and chemical solutions used for window cleaning. The water on the facade should be shed quickly and evenly since exposure to varying quantities of water causes uneven weathering and streaking patterns on the steel. At areas of extensive runoff, the water can be collected in gutters and piped away. Weathering steel gutters should be protected on the inside where accumulated dirt and debris keep the steel wet for prolonged periods.

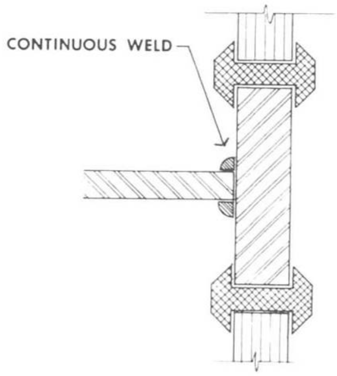
The direction of exposure of the steel and the degree of sheltering affect the corrosion rate[5]. Sheltered locations, which include not only areas under roofs and overhangs but also undersides of beams or leeward sides of columns, should ideally be avoided since sheltered steel will weather with a different color and texture at a slower rate. The bright orange color typical of the start of the weathering process can often be seen for years in sheltered locations, while nearby, the boldly exposed steel has attained its final purplish patina.

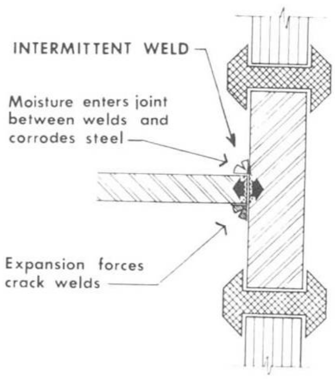
3. DETAILING WEATHERING STEEL

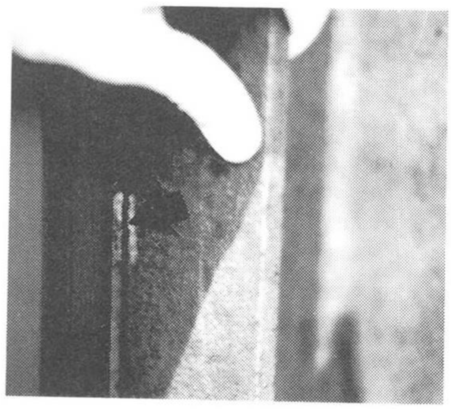
The properly detailed weathering steel facade exposes all steel surfaces to wet/dry cycles and avoids both sheltered areas and areas of constant wetness.

3.1 Faying Surfaces

All faying surfaces and crevices should be sealed in order to prevent moisture from penetrating and keeping the surfaces wet for a prolonged time. It is generally not sufficient to rely on bolts or intermittent welds to keep joints watertight. Unprotected faying surfaces and crevices will corrode and the corrosion products will tend to widen rather than to seal the joint. The formation of corrosion products exerts a high pressure which can break bolts and welds. Joints which are bolted or connected with intermittent welds should be protected with sealant and the faying surfaces should be painted.







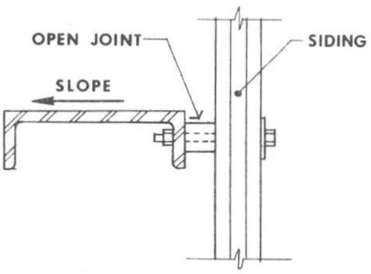
RIGHT: Protected Faying Surfaces.

WRONG: Unprotected Faying Surfaces Result in Broken Welds.

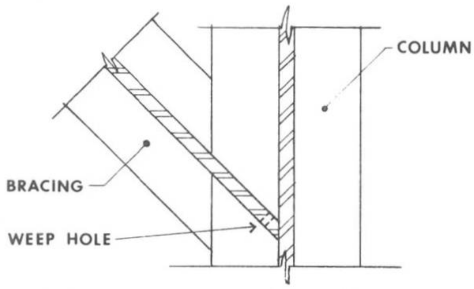
3.2 Non-Draining Surfaces

Ledges and steel surfaces should drain and areas where water can collect should be avoided. Where horizontal ledges or non-draining surfaces are unavoidable, the water can often be drained by weep holes. These holes should be of ample size to avoid clogging by rust or debris. If the surfaces are continuously wet, the steel in the affected area must be painted.

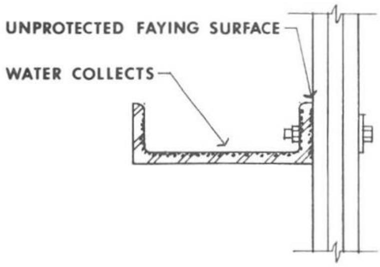
Horizontal girts for steel siding should be installed with flanges pointed down and with an open joint between the girt and the siding.



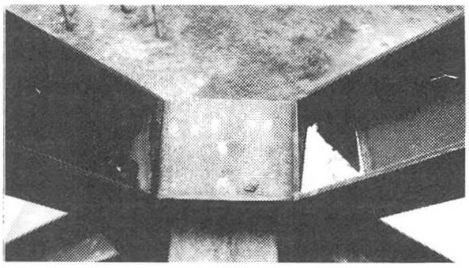
RIGHT: Horizontal Girt at Siding



RIGHT: Column Connection with Weep Hole



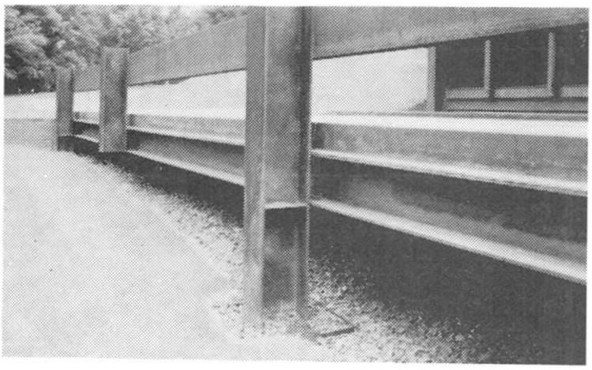
WRONG: Girt Collects Water, Unprotected Faying Surface



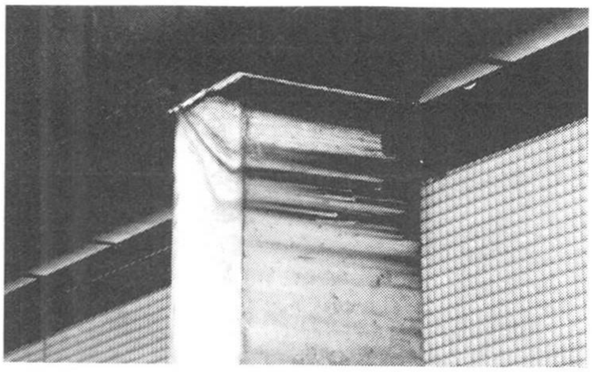
WRONG: Water Trapped in Cross Bracing Connection

3.3 Adjacent Materials

During the formation of the patina, the outer 2 - 3 mils of the weathering steel corrodes. The weathering process takes at least 2 - 3 years, but it can continue indefinitely at sheltered exposures or in rural environments. The soluable iron particles produced during weathering can cause staining and damage to adjacent materials and provisions must be made in the design to handle rust-laden runoff water. The runoff can sometimes be collected by gutters installed on the facade or overhangs and special flashings can protect walkways, parked cars, or other building elements. The visual effect of staining can be minimized by using materials with a rust brown color in areas of runoff such as colored concrete sidewalks or gravel strips.



RIGHT: Broken Gravel at Base of Column



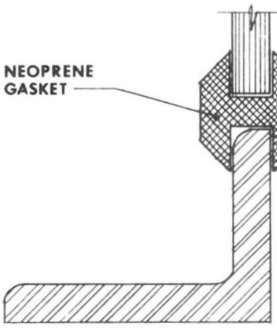
WRONG: Stain on Light Colored Concrete Column

Weathering steel in contact with other materials should be detailed not only to avoid staining, but also to avoid prolonged wetness at the contact surfaces. Steel in contact with concrete or masonry should be coated and the joint protected. Rusting of embedded weathering steel can cause cracking and spalling of surrounding concrete or masonry.

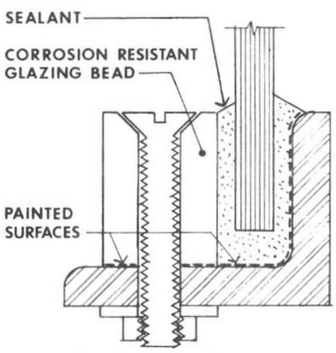
3.4 Glass Installation

The windows should be installed to avoid runoff from flowing onto glass surfaces. The windows can be recessed or drip flashings installed at the head. Only mild cleaning agents should be used for removal of rust and dirt from the glass and acid solutions must be avoided. All cleaning agents should immediately be rinsed off with clean water to prevent discoloration of the steel.

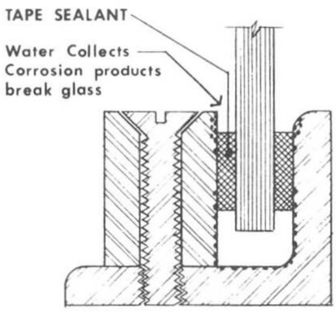
Fastening of the glass to the weathering steel frame should be designed to avoid trapping water which will result in glass breakage from expanding corrosion products. Neoprene gaskets or similar flexible material should separate the glass from direct contact with the steel.



RIGHT: Glass Installed in Neoprene Gasket



RIGHT: Corrosion Resistant Materials

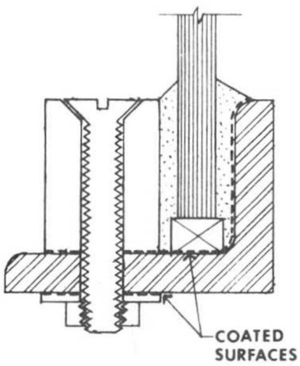


WRONG: Rust Expansion Breaks Glass

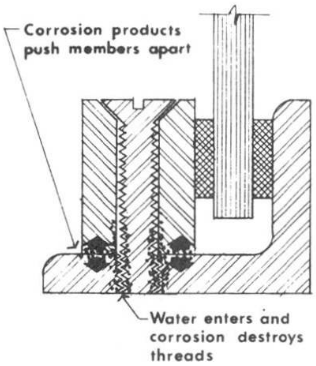
3.5 Joint Design

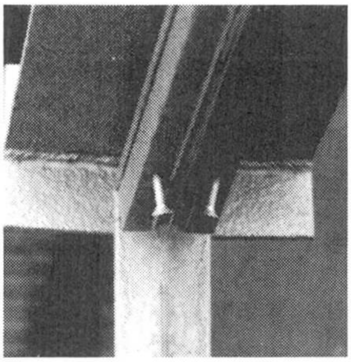
Weathering steel can be assembled by welding and special electrodes are available which provide the strength and the appearance of the base metal. The welded joints should be watertight and intermittent welding must be avoided unless the joints are sealed.

Machine bolts, high strength structural bolts, and various screws are all available in weathering steel material. Neither bolts nor screws will provide a watertight connection and the joint should be protected with sealant and the faying surfaces painted.



RIGHT: Paint Weathering Steel Faying Surfaces

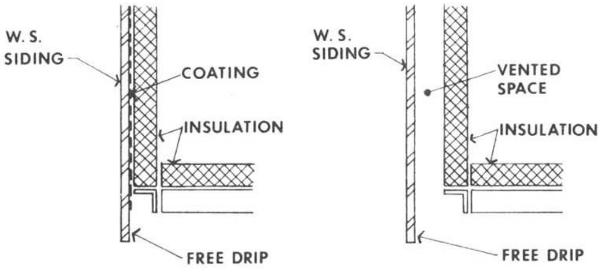




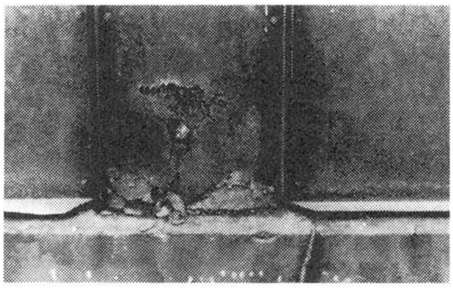
WRONG: Faying Surfaces Corrode, Screws Fall Out of Glazing Bar

3.6 Siding, Fascia, and Roofing Applications

The minimum thickness of weathering steel sheets should generally be greater than thicknesses normally used for coated sheets and not less than 0.0478 inch. The designer should consider that condensation often occurs on the inside surfaces of wall siding and roofing sheets as a result of high relative humidity within a building. Special problems arise when moisture collects in insulation placed directly against the steel sheets. To avoid corrosion, the interior face of the steel should be painted or a vented space provided between steel and insulation. Free drainage should be provided at the base of vertical siding and prolonged wetness both on the exterior, and especially on the interior face, should be avoided. The siding should terminate well above grade to avoid contact with snow or wet soil.

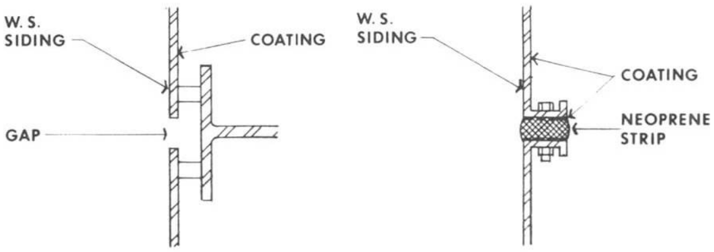


RIGHT: Interior of Siding Sheet Coated or Vented, Free Drip at Base

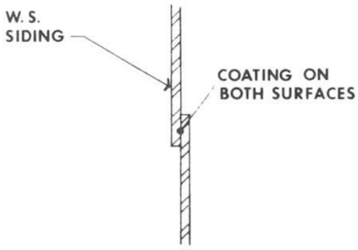


WRONG: Insulation Directly Against Uncoated Surface

External crevices such as butted joints in walls or overlapping joints in roofs require special consideration. Problems with vertical butt joints can be avoided by, instead, providing a gap or by caulking the joints. Lapped joints should be sealed and the surfaces coated.



RIGHT: Siding Butt Joints



RIGHT: Siding Lap Joint

4. CONCLUSION

Unpainted weathering steel with proper alloy composition in the right environment will develop a protective patina when exposed to alternating wet/dry cycles. The detailing of all exterior wall elements and connections must avoid creating pockets, crevices and faying surfaces where water can collect. Care must be taken in the selection and detailing of adjacent materials in order to avoid rust staining or deterioration. The unique properties of weathering steel make it a challenging material to use in designing a building facade. Properly exposed weathering steel has a textural and color variation common in natural materials. It is an appropriate material for building facades when the characteristics of the steel are considered in the design.

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