

## White Paper

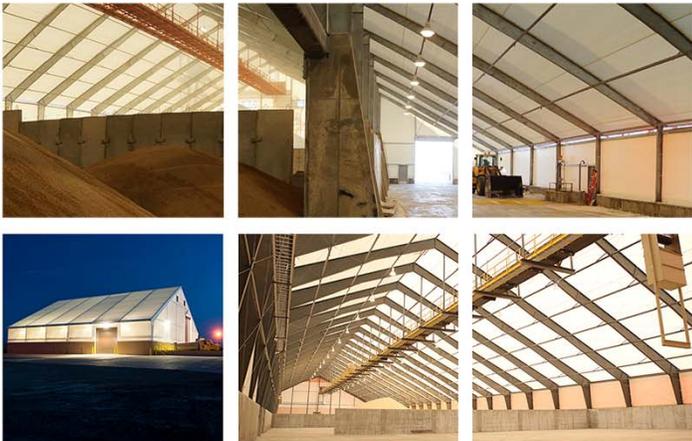
# Building for High-Corrosive Environments: How Legacy Fabric Structures Outperform



### INTRODUCTION

Corrosion is the deterioration of metal caused by the reaction of metal with the environment. The word “corrode” literally means “to gnaw to pieces.” Corrosion occurs in all major industries and is caused by humidity, sea air, chemicals, fertilizers, road salt and more. Corrosion significantly increases maintenance costs and shortens the lifespan of industrial buildings.

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## Costs, Types and the Most Corrosive Environments

According to the National Association of Corrosion Engineers, in 2002 the direct cost of infrastructure corrosion was over \$22 billion in the United States alone. Adjusted for inflation, the direct cost of corrosion in 2013 was over \$42 billion in replacement of corroded equipment, preventive maintenance such as painting, product contamination and equipment shutdown, and time lost to safety concerns. Experts predict that at least 25 to 30 percent of annual corrosion costs could be saved if corrosion management practices were employed. But managing corrosion costs both time and money. Fortunately, employing best practices like proper ventilation, separating dissimilar materials and using protective coatings all result in significant savings.

Some corrosive environments are naturally occurring, and others are created or compounded by the storage of corrosive products. Humid locations, especially those in proximity to the sea, create the most naturally occurring corrosive environments because of the salt from the sea air. Even more vulnerable are buildings used for storing corrosive materials such as sulfur dioxide, acids, alkalis, dry and liquid fertilizers, salt products,

wastewater, sewer sludge, livestock, manure and compost. A byproduct of many of these materials is chloride, which has been identified as one of the most destructive corrosive chemicals to steel and a primary cause of premature deterioration of steel-clad buildings.

Galvanic corrosion, a common type of corrosion, is caused by an electrical process that takes place whenever different types of metals are connected by an electrolyte, such as moisture. This phenomenon creates a direct current, like that of a DC battery. When this process occurs, electrons flow from the least noble metal (the higher energy state – the anode) to the most noble metal (the lower energy state – the cathode), causing galvanic corrosion. This causes the metal with the highest energy state - the less noble metal – to corrode.

Crevice corrosion occurs when a small volume of stagnant moisture is in contact with a metal (typically within a crack) long enough for the moisture to penetrate the protective coating. The crack must be big enough for moisture to get in, but small enough to create a stagnant zone. Crevice corrosion can occur in cracks just a few thousandths of an inch wide.



Figure 1: Ventilated fertilizer storage





Figure II: Interior liner to protect the steel frame

Some areas where crevice corrosion can develop include:

- Micro-cracks in the protective coating created during forming or anywhere metal has been damaged, bent or folded;
- Crevices beneath fastener heads, especially over-driven fasteners, can create dents in the metal where water can pool;
- Spaces where fibrous fastener gaskets exist that wick water beneath the gaskets where it can remain long enough to cause corrosion.
- Spaces where metal pieces overlap and water gets trapped between the two pieces.

Filiform corrosion looks like a thin filament and is usually found beneath paint, but also can be found under other protective coatings. Filiform corrosion normally starts at small or microscopic defects in an outer coating. The filament is made up of an active head and a corrosion product tail. An active head means that corrosion only takes place at the head of the filament – this type of corrosion won't spread out uniformly but will only move forward from the tip of the filament. It's generally a cosmetic issue and

doesn't weaken metal structurally. This type of corrosion begins at panel edges and usually moves in a straight line. Filiform corrosion occurs most often in environments where relative humidity is between 65% and 90%. Humidity below 65% doesn't affect metal. Humidity above 90% can cause corrosion to appear as blistering.

#### Discouraging Corrosion

Fortunately, it's possible to discourage corrosion. Modern methods of corrosion protection offer immediate and long-term cost savings, improved working conditions, increased efficiencies and enhanced safety.

There are several corrosion-resisting coatings on the market. Options include in-line galvanizing, hot dip galvanizing, oxide primers, paint, epoxy paint, spray-on rubber and treated lumber.



Figure III: Hot dip galvanized steel members



The most effective method of deterring corrosion caused by moisture is through a process called hot-dip galvanizing, in which a zinc coating is electrochemically applied to steel using a series of chemical baths. Hot dip galvanizing is a multi-step process that ensures the steel is fully cleaned and pre-treated before the zinc coating is uniformly applied.

Another option is in-line galvanizing, which is a coating of zinc and chromate with a clear polymer topcoat. Often, this process is known by the brand names Flo-Coat® or Gatorshield®. In-line galvanized tubes are treated before the trusses are welded. During the welding process, the coating is burned off the inside and outside of the tubes. This leaves the welded areas, the most important areas to protect, extremely vulnerable to corrosion.



Figure IV: Solid plate steel frame

Hot dip galvanizing adheres a minimum of 3.9 mils of zinc to all inside and outside surfaces after manufacturing, providing maximum protection from corrosion. In-line galvanizing applies just 0.9 mils of zinc before manufacturing, leaving the inside steel exposed to corrosive elements.

## Building Material and Corrosion Prevention

When it comes to supporting frames for buildings in corrosive environments, the choice and design of materials contributes significantly to stopping corrosion.

Wood has been a material of choice for many years, but given cost and other issues, wood is increasingly being replaced by steel frames. Steel frames are usually seen in two designs – hollow tube open web truss, and solid I-beam.

Although wood was the material of choice for corrosive environments some years ago, today this route is significantly more expensive than all other options. Cost aside, wooden buildings are not as durable as they may seem, since corrosion can play havoc with nails, fasteners and brackets.



Figure V: Salt storage fabric structure

Wood, even treated lumber, does deteriorate over time. Wood splits because it is constantly drying out. Because of the variety of wood species and types, there are a wide range of strengths and properties to consider.

Joints with pressure perpendicular to the grain in the wood are a common problem in wooden structures. The load configuration may cause a compressive and tensile failure because allowable compressive to wood grain values are notoriously low.

Steel tube open web trusses are efficient to mass manufacture, but they introduce significantly more maintenance expense as well as exposure to corrosive elements down the road. Corrosion will likely find its way inside of the tube, which is usually impossible to detect or treat. To prevent steel manipulation flaws from introducing a path for



corrosion, some open web trusses are first manufactured and then hot dip galvanized.

A rigid building frame is made of solid plate steel. This is in contrast to an open web truss made of HSS chords and webs. Rigid frames are typically designed and proven by sophisticated FEA software with manual quality checks. This software allows for complete design, customization, timely estimates, proposals and solutions.

Since rigid frames have no hollow spaces, these have a clear advantage over hollow tube open web trusses. In addition, the thickness of steel in rigid frames is many times greater than most parts of a truss. And when a protective coating is applied to a rigid frame (usually hot dip galvanizing), the entire rigid steel frame section is treated at once through a hot-dip process. The more zinc available to protect the product, the longer the product will last, especially in a corrosive environment.

Coated steel cladding is one of the most popular exteriors for industrial buildings. But despite the rust-inhibiting coatings that are applied to the cladding before or after manufacture, they are vulnerable to galvanic corrosion of the non-steel

screws and nails, crevice corrosion in scratches, dents or punctures, and filiform corrosion in scratches and moist, sealed areas.

For these reasons, fabric-covered buildings are seeing rapid adoption, particularly when buildings are used in highly corrosive environments. Let's take a closer look at why.

Since the steel frame components of a fabric building are inside the structure and covered by a waterproof membrane, these frames are protected from moisture. In steel-clad buildings, sheets of metal are used for roofing and siding. And as mentioned earlier, these sheets are nailed or screwed together, which creates tiny openings for outside moisture and chemicals to seep inside and initiate corrosion. In addition, moisture will often penetrate areas where steel overlaps, creating a ripe environment for corrosion.

Most corrosive materials have no impact on the threads and polymer coatings used to create architectural fabric. Fabric coverings are usually much easier to inspect, and maintenance costs are a fraction of steel or wood cladding.



Figure III: Conveyor system for commodity and fertilizer storage





Figure IVI: Good design for corrosive salt storage

In many fabric buildings, the roof fabric is made of large panels and not attached to many of the frames. These buildings are typically called mono-covers. As this system experiences wind load, the fabric lifts off all the frames that are skipped over on the leeward side of the building as the roof experiences suction, and all the forces of the fabric are applied to the two trusses where the fabric is attached. This is how many building failures occur.

Mechanical winch blocks exposed on the wall are often used to secure the fabric roof to the building. These blocks are typically the first to experience substantial corrosion. If a winch block corrodes and fails, the roof fabric may fly off the building, leaving the contents completely exposed to the elements.

On the Legacy system, roof fabric is attached to the frame via a keder track allowing for greater fabric tension both horizontally and vertically. Installation of the fabric is much safer because the roof panels are always under full control as each panel is fed into the keder track. Legacy also utilizes industry-exclusive methods to tension and secure our fabric to avoid the use of winch blocks.

## Good Design for Corrosion Prevention

In both fabric and steel-clad buildings, the first line of defense against corrosion is good design. Unfortunately, with many structures, preventing corrosion through design often takes a backseat to cost, aesthetics and functionality. At the design stage, preventing corrosion involves creating access points for applying coatings at regular intervals, sealing or eliminating lap joints where crevice corrosion can occur, eliminating moisture traps, providing good drainage and ventilation to minimize moisture, and taking into consideration the other materials with which steel will come into contact.

Because of the materials used as well as our designs, Legacy buildings are designed for easy inspection of areas where corrosion could get started. All areas are easy to inspect, and if necessary, repair.

Particularly in solid steel frame fabric buildings, a fabric liner can be easily and affordably attached to the underside of the steel frame to add protection



against corrosion, creating a maintenance-free system. Legacy liners seal the building from the inside out to prevent any corrosive materials from contacting any part of the steel framework. In fact, some building manufacturers will extend their warranty when this is installed as part of a new building.



Figure V: Protective awning over a doorway

Reducing moisture and humidity inside the building is also critical for preventing corrosion. Gravity ventilation, easily achieved by adding peak vents and mesh soffits, keeps a constant flow of fresh air in the building and dramatically reduces humidity and moisture levels.

### Corrosion and Total Cost of Ownership

When choosing the type of building to use in environments where corrosion is a concern, it is critical to consider more than the original purchase price. The more important dollar amount is the total cost of ownership.

There are many variables to consider, such as corrosion prevention and maintenance, design type, design time, construction time, energy usage and more.

When steel-clad buildings are used in corrosive environments, the exterior areas most vulnerable are roof sheets and siding sheets. In a corrosive environment, the cladding on a steel building can corrode in as little as 5-10 years, and the interior walls may only last 8-12 years without regular maintenance. Because of this, most manufacturers of steel-clad buildings won't provide a warranty when used where corrosives are present.

In hollow tube open web truss structures, whether steel or fabric clad, once corrosion enters the inside of the hollow tubes it is nearly impossible to detect and within a few years the entire structural integrity can be compromised.

Even when a fabric membrane becomes worn with age, usually after 20 or more years, the replacement cost is about 1/3 the cost of completely replacing a corroded steel-clad building. Repairing the covering on a fabric building can cost as little as \$2 per square foot. With installation costs, replacement steel panels for a building's sides or roof can easily cost up to \$7 per square foot.

Fabric buildings are usually warranted by the manufacturer when used in corrosive environments,



Figure VI: DOT salt, sand and deicing



and they require less maintenance: No painting, no replacing shingles, no loose siding to repair, no special tools to make repairs to the covering, etc.

Most fabric structures install 2 to 4 times faster than steel buildings. Wood buildings are even more labor intensive. A fabric structure requires .02 to .03 man hours per square foot, as compared to steel buildings, which require .04 to .07 man hours per square foot.

A key benefit of fabric buildings is that they provide natural light. Fabric roofs offer up to 12% translucency to allow natural light to permeate the structure. Most facilities will still need artificial lights for nighttime work, and to provide adequate illumination on stormy or overcast days. During normal daylight hours, however, fabric roofs effectively eliminate the need for artificial lighting, thus reducing energy costs, making a building more energy efficient and creating a more pleasant, shadow-free working environment.

Fabric is also a non-conductive building material, better retaining the inside temperature rather than magnifying the outside conditions. This keeps the building cooler in the summer and warmer in the winter. Added to a reduced need for artificial lighting, the energy savings over a building's lifetime can be substantial.

Buildings are often designed to accommodate live and hanging loads to maximize the building's efficiency. If an open web truss building requires a hanging load, it will put enormous stress on the frame, which in time can cause weak points that give corrosion a foothold. Because open web trusses have a lot of vertical and horizontal deflection, conveyors will require extra maintenance to continue running true. If there's a lot of movement, then recalibration is required to avoid

wear on belts - in addition to other costly maintenance.

If the building is located in a harsh weather environment, snow and wind loads can significantly stress the trusses. Not only are rigid steel frame fabric buildings more durable in corrosive environments, they are also more resilient to hanging conveyer loads as well as seismic, snow and wind loads.



*Figure IX: Rigid steel frame design*

Rigid frame fabric structures allow you the option of using cast-in-place concrete walls or precast interior wall panels. Cast-in-place walls are a more permanent option, with a longer install timeframe, whereas precast walls can be installed quickly and give you the flexibility of relocating if need be.

Fabric buildings on a rigid frame can be constructed to nearly any dimension, roof pitch and peak height. In addition, they can be uniquely shaped to fit creative designs and odd sized lots. This includes offset peaks, multi-level columns, sidewall dormers, lean-tos, and mono-slope roofs.

## Conclusion

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The best time to prevent corrosion is in the building design. Stopping corrosion before it starts will save money and time in the long term, contributing to a lower total cost of building ownership. Fabric structures on a rigid steel frame have a drastically lower risk of corrosion in any environment.

