Should We Be Concerned About Corrosion?

Material choices when renovating steel fire towers

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Pieces of the 100-year-old cross braces from the St. Regis Fire Tower in Franklin County, NY were used in this investigation. The old braces were replaced by the Friends of St. Regis Fire Tower with newly manufactured hot dipped galvanized braces in 2018 and 2019	The Rock Rift Fire Observation Tower is located on Tower Mountain above the Cannonsville Reservoir in the Town of Tompkins, Delaware County, New York. The results of this investigation will be used in the decision-making process for the tower's restoration.

Introduction

When starting on a fire tower renovation project, we may start by considering logistics, cost, fund raising, and other immediate concerns. However, it is also important to consider the effects of corrosion by common materials used in fire tower restoration projects. Questions arose during early planning sessions for the restoration of the Rock Rift fire tower. Which lumber choices are likely to cause corrosion due to either modern pressure treatment formulations or the properties of rough sawn hardwoods? Can the corrosive effects of the lumber be mitigated by a barrier? Dissimilar metals in contact with each other in outdoor environments often give rise to galvanic corrosion. Are galvanized nuts and bolts a better choice than stainless-steel to attach stair treads on a galvanized fire tower?

Two, consecutive one-year studies were completed examining the potential for corrosion for fire tower restoration. Four types of lumber were paired with aged, galvanized steel from the St. Regis fire tower and set outdoors for one year. The second one-year study was designed to examine the corrosion potential/resistance of 18-8 stainless-steel (SS) vs hot dipped galvanized (HDG) nuts and bolts when used to attach white oak lumber to galvanized steel. These studies were undertaken to inform the planning for the renovation of the Rock Rift Fire Tower in the Town of Tompkins, Delaware County, NY.

White oak stair treads have been used to replace old stair treads on fire towers as part of modern rehabilitation efforts. Beebe Hill Fire Tower and Page Pond Hill Tower are two New York towers that have untreated rough-sawn white oak stair treads in good condition. White oak lumber is known to be strong, rot resistant, and acidic enough

to corrode metals in contact with it especially when used in an outdoor location where precipitation will frequently wet the wood. Typical pH values of oak range from 3.35 to 3.9.

White oak lumber is a forest resource local to many New York State forest fire observation towers. When towers were originally purchased from the manufacturers, lumber for the stair treads, landings, and cab flooring were left up to the purchaser to source and supply. Historically the exposed lumber was surface treated, or pressure treated, with a variety of preservatives that were not corrosive to galvanized materials. These preservatives included creosote, penta-chlorophenol, and in later years copper-chromium-arsenic (CCA). However, their toxicity to people and wildlife as well as their mutagenic and carcinogenic effects have curtailed their use today.

	Image shows one of two test racks during the 2020 -2021 corrosion study.

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Methods

2019 to 2020 investigation

Four lumbers were examined on an outdoor test rack attached to pieces of fire tower angle iron:

- Rough-sawn white oak (WO)
- Alkaline Copper Quaternary pressure treated lumber (ACQ)
- Micronized Copper Azole pressure treated lumber (MCA)
- Ecolife II pressure treated lumber (EL2)

Six samples of each lumber were attached to the old, galvanized steel from the St. Regis tower without any barrier materials placed between the lumber and the steel. Two samples of each lumber were attached to steel with a barrier of Rust-oleum® 5200 System DTM Acrylic paint. Two samples of each lumber were attached to steel pieces with a barrier of Grace® Water and Ice Shield as a barrier between them. This material is a membrane of rubberized asphalt adhesive backed by a layer of high density cross laminated polyethylene film. (Caution: avoid barrier films that contain carbon black as a filler. The carbon black will react with stainless steel and result in corrosion of the stainless-steel.) The samples were attached to frames and were set outdoors in Chenango County, NY from November 2019 to November 2020.

	Image to the left shows the test rack from the 2021 – 2022 study comparing the corrosion of oak lumber on stainless-steel vs. hot dipped galvanized nuts and bolts. This image was taken 10 months after the start of this part of the two-year study.

2021 -2022 investigation

Galvanized steel from the St. Regis fire tower was attached to samples of white oak lumber separated by a barrier film of Grace® Water and Ice Shield. Half of the samples were attached with stainless-steel bolts and half with hot dipped galvanized bolts. Also, SS bolts and HDG bolts were attached to nylon plates with nuts of the same and different composition.

Results

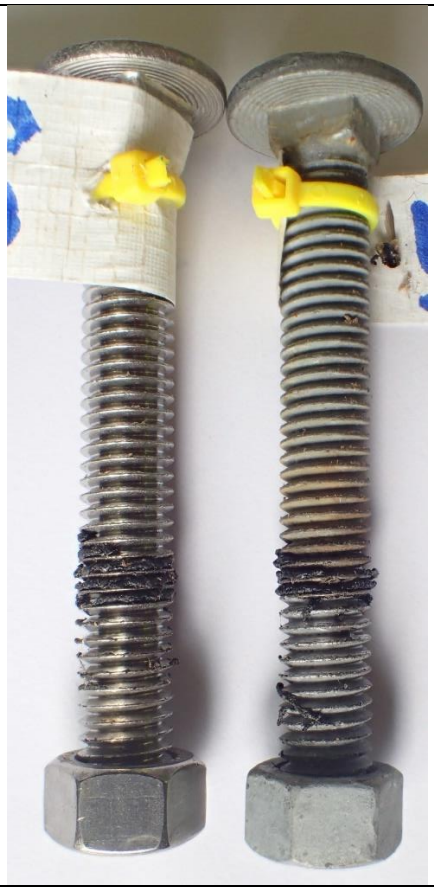
In the 2019-2020 study, the bolts through the white oak lumber showed the most corrosion. This occurred in the samples between the white oak and the bolts even when a barrier was used between the angle iron from the St. Regis fire tower and the oak lumber. Moderate corrosion formed along the threads of the bolts from the Alkaline Copper Quaternary (ACQ) pressure treated lumber samples. Light corrosion was noted along the bolts that were imbedded in the Micronized Copper Azole (MCA) pressure treated lumber. MCA lumber was developed to be less corrosive than ACQ. This demonstration supports that claim. Of the four lumbers used, the MCA formulation used in this investigation is the only one labeled for ground contact. The others are only for non-contact or above ground use. Corrosion is not evident on the bolts in the Ecolife II treated lumber (EL2).

The first study demonstrated that white oak lumber attached to a galvanized steel angle iron without a barrier film, resulted in significant rusting and corrosion within one year. With a barrier film, the steel from the cross braces was protected. The ice and water shield is quick and easy to apply and does not require the drying time of a paint. The Grace® Ice and Water Shield stood up to removal of the lumber and maintained its integrity. The Rust-oleum® 5200 System DTM Acrylic paint also protected the steel. Portions of the paint pulled away from the steel upon disassembly.

No corrosion was evident on the galvanized steel angle iron connected to the Alkaline Copper Quaternary pressure treated lumber (ACQ) or the Micronized Copper Azole pressure treated lumber (MCA). Corrosion in the form of minor rust stains were found on the steel along the margins of some samples of the EL2 – Ecolife II lumber.

	
The upper portion of this image shows steel sample # 06 A with rust on the leg of the angle iron. The lower portion shows the piece of rough sawn white oak lumber that was attached to this piece of steel. It shows a transfer of rust from the steel angle iron.	Sample of bolts that connected wood to steel for 1 year. Bolt through ACQ # (Top Left), Bolt through white oak (Top Right), EL2 (Bottom Left), and Bolt through MCA (Bottom Right)

The 2021-2022 study examined the performance of 18-8 stainless-steel vs hot dipped galvanized bolts used to attach white oak lumber in an outdoor setting. The stainless-steel bolts appeared to be unaffected by the acidic white oak.

	18-8 stainless steel bolt (left) shows no evidence of corrosion after one year of weathering connecting white oak lumber to century old, galvanized steel from the St. Regis fire tower. (Sample 06-A) Hot dipped galvanized bolt (right) shows corrosion after one year of weathering in upstate New York, connecting white oak lumber to galvanized steel. (Sample 15-B) Both bolts show a black residue from the Grace® Water and Ice Shield below the portions that were embedded white oak lumber.

The hex nuts above were paired with bolts of similar and dissimilar metals and fastened to sheets of nylon. They were placed outdoors for one year. Sample 3A HDG nut attached to HDG bolt, Sample 2B HDG nut attached to SS bolt, Sample 2A SS nut attached to HDG bolt, and Sample 3B SS nut attached to SS bolt.

Discussion

The 2019-2020 study found little visible corrosion of the angle iron from the various pressure treated lumber, though some corrosion was seen on most of the HDG bolts. The 2021-2022 study found no visible corrosion between the 18-8 stainless-steel bolts and the white oak or the galvanized angle iron. Connecting dissimilar metals to each other is typically discouraged due to their potential for galvanic corrosion. In both one-year experiments it was anticipated that the corrosion would be more significant. So, what may explain the results from these studies?

Requirements for Galvanic Corrosion

- Two or more metals with different corrosion potentials (the copper in the pressure treatment of lumber allows the treated lumber to act as a metal)
- Contact between the two metals or metal bearing substances
- A conductive electrolyte solution such as water that creates a path for electrical conduction

However, the relative size matters as to the current density generated by a galvanic reaction in the anode. In both one-year studies, the galvanized steel is the anode. The relative surface area of each of the exposed metals is a determining factor. If the area of the cathode is very large, and the anode is very small, the current density produced is likely to cause the anode to corrode. That is not the situation in this experiment with the angle iron. This is not the situation in typical steel fire tower restoration either. Some of the published corrosion research examined galvanized nails, decking screws, or joist hangers (with a thin galvanized coating) tested in or supporting, a pressure treated plank (The copper in the lumber pressure-treated formulation is the cathode when paired with galvanized steel.). In those published studies, the relative surface area of the cathode was indeed, very large.

The 2021 to 2022 study was designed to look for corrosion of 18-8 stainless-steel hardware and its influence on the connected HDG angle iron. The study compared the performance of the SS to the corrosion of HDG bolts when used to connect white oak lumber to HDG steel in an outdoor setting (annual precipitation of about 43 inches). The stainless steel did not promote or show visible signs of corrosion. Rust formed along the threads of the HDG bolts.

The 2021 to 2022 study also examined samples of mixing dissimilar metals. SS nuts were connected to HDG bolts. HDG nuts were connected to SS bolts. Nuts and bolts of the same material were also connected to compare to the effects of mixing dissimilar metals. It was noted that there was some corrosion on the internal threads of the HDG nuts connected to HDG bolts. The most corrosion was found when a HDG nut was attached to a stainless-steel bolt. Corrosion was not evident on the SS nuts when attached to a HDG or SS bolt (see image above). This result demonstrated that with a larger surface area of the cathode material (SS) and a much smaller surface area of the anode, (HDG) greater corrosion will occur at the anode.

Going Forward

The study comparing stainless-steel bolts through white oak shows that stainless-steel with its higher cost is justified to reduce corrosion, increase the useful life of fire tower stairs and decks, and to reduce maintenance costs when individual boards require replacement.

A galvanic reaction will occur between most available formulations of pressure treated lumber and galvanized steel. We are not restoring the fire towers for the next 10 or 20 years. We are restoring them so that their structures and legacies are preserved far into the future. Only three formulations of pressure treated lumber were examined in this study. The Ecolife II pressure treated lumber showed a corrosive effect on the fire tower steel. Perhaps it is prudent to install a barrier system during fire tower renovation between all lumber and galvanized steel. The corrosion of hot dipped galvanized angle iron and bolts by white oak is due to the low pH of the wood rather than by a galvanic reaction. As demonstrated in these studies, installing a barrier between white oak and galvanized steel, and using 18-8 stainless-steel nuts and bolts is very effective in minimizing corrosion.

Special Thanks

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