Fasteners for Exposed Wood Structures

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Abstract

This paper provides an overview of the use of fasteners that are appropriate for exposed wood structures. Several types of fasteners are reviewed, and physical and chemical explanations for fastener corrosion are provided. Recommendations for long-term performance are given.

Introduction

One of the most important considerations in building a wood outdoor structure is its performance as a structural system. Unlike the skeleton of a conventionally framed wood house, many outdoor structures are built without the sheathing, siding, and roof that provide structural stability and protection from the environment. Fully exposed to the degrading effects of the weather, structural members must be properly designed and connected to ensure long-term, safe performance. Structural support comes from not only the proper sizing and placement of the posts, beams, joists, and other members used in the construction, but from the connection of these members. This paper discusses the fasteners recommended for use in outdoor structures.

Fastener Types

The overall integrity of any wood structure depends on how its components are held together. Therefore, it makes little sense to properly size the wood members only to improperly fasten them. The most common fasteners for wood construction are nails, screws, lag screws, and bolts. Metal straps and hangers of various types are also available. Fasteners used for wood construction are typically manufactured from mild steel, although many types and sizes can be made from stainless steel, brass, and bronze. Nails and screws are the most common type of fasteners for attaching members in light-frame structures. For fastening heavy members of an outdoor structure, such as the beam to the posts, lag screws or bolts are the fasteners of choice.

Holding power and corrosion protection are probably the two most important concerns when choosing fasteners. Improperly specified fasteners can loosen when the wood shrinks and swells as a result of moisture cycling of exposed lumber. Rusting of steel fasteners not only weakens the fastener, but the chemical reactions involved in corrosion can also weaken the wood surrounding the fastener.

Nails. Smooth-shanked nails can lose some of their withdrawal resistance when exposed to wetting and drying cycles, resulting in nail pop-up and loosening of connections. Through the use of a wet-service, strength-reduction factor, the National Design Specification (NDS) (AFPA, 1991) accounts for wood shrinkage from around smooth-shanked nails as the moisture content changes from wet to dry. However, better performance in withdrawal can be expected by using deformed shank nails to resist the effects of severe wetting and drying of exposed wood structures. Two commonly available deformed shank fasteners with the capacity to retain withdrawal resistance are spirally grooved and annular grooved (ring-shanked) nails.

Screws. Common wood screws have been used to fasten wood for decades; however, the more recently developed multipurpose screw has found common use in wood-deck construction, primarily to fasten deck boards to joists. These fasteners have a thread design that can be driven fast, and they have good holding power. Unlike common wood screws, they are straight shanked. Commonly available in 2- to 3-in. (50- to 75- mm) lengths, multipurpose screws are available with a Phillips head or square recess head, and are most easily driven with a power drill.

Multipurpose screws are not intended to fasten joist hangers to beams and will not equal the design capacity of the hanger. Only manufacturer-specified hanger nails should be used to attach hangers.

Screws have an advantage over nails in that they are more easily withdrawn to remove defective or damaged members. They are also effective in drawing down cupped or twisted decking boards into a flat position, and will resist withdrawal over time.

Lag Screws and Bolts. Lag screws are commonly used to fasten one member to a thicker member where a through bolt cannot be used. Pilot holes must be drilled for lag screws, and the screw must be fully inserted to be effective. According to the NDS (AFPA, 1991), for softwood species typically used in outdoor structures, pilot holes should be about 60% to 70% of the diameter of the screw for the threaded portion, and the full diameter for the unthreaded shank. Make sure the lag screw is long enough so that at least half of its length penetrates the thicker member.

Bolts offer more rigidity and typically more load-carrying capacity than lag screws; however, their use is obviously limited to situations where a hole can be drilled completely through the members to be connected. Holes drilled for bolts should be no more than 1/16 in. (2 mm) larger in diameter than the size of the bolt used. As with lag screws, washers should be used under both the head of the bolt and nut to distribute the bolt force over a larger area and limit crushing of the wood. Machine bolts are a better choice than carriage bolts because carriage bolts are manufactured for use without washers. Dome-head bolts, typically used in heavy timber construction, are also a good choice. After drilling holes for fasteners, it is important to immediately saturate the holes with a preservative, such as copper napthenate. After about one year, bolts should be retightened, and thereafter checked for tightness every year or so.

Joist Hangers and Metal Straps. Joist hangers, metal straps, and other hardware are often used in outdoor wood construction; however, most are intended for indoor use. Although typically electroplated with zinc, their long-term corrosion resistance in exposed environments is unknown. Some manufacturers make these products from stainless steel or apply heavy coatings of galvanizing to increase longevity.

Wood/Metal Interaction

Wood and metal are compatible in most construction; however, if there is sufficient moisture at the wood-to-metal interface, some corrosion can be expected with susceptible metals. The corrosion of metal in contact with moist wood is an electrochemical process. The rate and amount of corrosion depends on the metal, the conductivity of the wood, and the duration and temperature of the surrounding environmental conditions. The risk of corrosion depends somewhat on the wood species, presence of external corrosive contaminants, and condition of the wood (untreated or treated with certain chemicals). Not only does moist wood in contact with metal cause some corrosion, but the chemical byproducts of corrosion can result in a slow deterioration of the wood adjacent to the metal. As a result, the fastener will lose cross-section and there will be some enlargement of the hole around the fastener. Additionally, most woods are slightly acidic, which may accelerate the corrosion of the steel (or galvanized coating).

If the moisture content of the wood is less than about 18%, the metal corrosion rate is minimal (Baker, 1988). Remember, however, that only the moisture of the wood in contact with the metal is important. This means that metal, such as a fastener that has been cooled by ambient conditions and kept cool by the surrounding wood, can corrode when it becomes wet by condensation, such as on a warm, humid day following a cool night in the early spring. The condensed moisture wets the wood at the wood-to-metal interface. At first, this results in only an iron stain on the surrounding wood surface, but in time, the iron will chemically damage the wood structure and weaken the joint. This type of corrosion is responsible for the failure of many unheated wood structures, such as barns and sheds, in areas with humid days and cool nights.

Some fasteners are corrosion resistant because of a protective coating, and some are resistant because of the properties of the metal or alloy. A fastener can be resistant to corrosion in one environment, but corrode in another. A good example is aluminum, which will perform well in untreated wood exposed to the environment, but will corrode rapidly in wood treated with preservatives that contain copper.

Coated Steel Fasteners

Most steel fasteners are uncoated because they are intended to be used in protected environments (indoors). Obviously, if these fasteners are exposed to the weather, they can rapidly corrode. In the mildest of cases, this corrosion can lead to unsightly staining of the wood. In more severe cases, it can cause complete disintegration of the fastener and a total loss of structural strength (Baker, 1988).

Several types of coatings are used to protect steel fasteners. These include chromate paint, plastic, ceramic, and metal coatings (galvanizing). Adhesive type coatings (e.g., paint and plastic) can flake off when driving the fastener, compromising the protection it was intended to provide.

General Guidelines for Fastener Use

1. At a minimum, use hot-dipped galvanized metal in outdoor wood structures.
2. Use stainless steel fasteners for added durability in severe exposures.
3. Always fasten a thinner member to a thicker member.
   (a) A nail should be long enough to penetrate the recieveing member a distance twice the thickness of the thinner member.
   (b) A lag screw should penetrate the larger member at least half of the length of the screw.
4. Reducing splitting of boards when nailing by:
   (a) Placing nails no closer to the edge than one-half of the board thickness and no closer to the end than the board thickness,
   (b) Pre-drilling nail holes,
   (c) Blunting the nail point,
   (d) Using greater spacing between nails, and
   (e) Staggering nails in each row to prevent splitting along the grain.
5. Avoid end-grain nailing when possible.
6. When drilling holes for lag screws or bolts, saturate the hole with a preservative, such as copper napthenate, to prevent the migration of decay fungi into the untreated part of the member.
7. Use washers with bolts and lag screws to reduce crushing of the wood.
8. Tighten bolts and lag screws one year after construction, and thereafter, check tightness periodically.

While the coating protects by providing a barrier between the steel and the environment, galvanized coatings sacrificially corrode to protect the steel. When the coating is gone, the steel will begin to corrode. The galvanizing can be applied by electroplating, mechanical plating, or single- or double-dipping the fastener in molten zinc (hot dipped). The thickness of the coating is very important; a thicker coating provides additional protection.

Most manufacturers coat fasteners to the standard ASTM A153-87 (ASTM, 1987), which specifies a minimum coverage of 0.85 oz/ft^2 (259 g/m^2) of zinc. This is probably thick enough for most outdoor structures in dry-weather areas. Although the corrosion process typically proceeds over many years, our research shows that commonly available coated fasteners simply do not have a thick enough plating for long-term protection (20 yr) in severe (underground or high humidity) environments (Baker, 1992). Thicker coatings [1.0 oz/ft^2 (305 g/m^2)] are available and should be used. in wetter situations. Coating specifications should be available from the fastener manufacturer.

Unfortunately, many building contractors use only electroplated nails for outdoor construction because they are readily available for use in pneumatic nail guns. Hot-dipped galvanized fasteners are produced for pneumatic nail guns, but their availability is limited.

Stainless Steel, Copper, and Aluminum Fasteners

The chemical properties of stainless steel make it resistant to corrosion. Although more expensive than hot-dipped galvanized fasteners, stainless steel is a more durable option, particularly for outdoor structures that are located in high-humidity areas or that remain wet for much of the time. Research has shown that little long-term degradation of stainless steel fasteners occurs even in the most severe exposure conditions (Baker, 1992). Also, the use of stainless steel fasteners reduces the possibility of staining around the fastener.

Although stainless steel fasteners are available in several grades, the American Iron and Steel Institute's (AISI) 300 series (e.g., 302,303,304, and 316) is appropriate for use in outdoor wood structures. While the price of stainless steel fasteners and hardware can be several times higher than the price of mild steel, their use is justified. The relatively small cost increase to the overall structure adds significantly to its reliability and long-term performance in severe conditions.

Copper, usually of rather high purity, and an alloy, silicon bronze, are often used to fasten wood (wood shakes, shingles, and in boat construction), although usually not in conventional structural applications.

Aluminum is suitable for use with untreated wood and wood treated with an oil-type preservative. However, aluminum should never be used in contact with wood that is treated with a waterborne preservative that contains copper, such as chromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), or ammoniacal copper arsenate (ACA).

Corrosion in Untreated Wood

For an isolated fastener in moist wood, crevice corrosion can occur (Baker, 1988). This is the type of corrosion observed in crevices along riveted and welded seams of metal tanks and pipes. The head of a steel fastener in moist wood usually acts as a cathode and the shank in the "crevice" serves as the anode. At the anode, iron goes into solution in the form of ferrous ions. As corrosion proceeds, hydroxides of iron precipitate. This leaves an excess of hydrogen ions in the surrounding water and the pH decreases. In addition, the wood fiber is chemically degraded as the ferrous ions are oxidized to ferric ions (Baker, 1988).

Dissimilar metals that are in physical contact with each other can result in galvanic corrosion, in which the corrosion of the least corrosion-resistant metal increases and the corrosion of the most corrosion-resistant metal decreases. Because of this, the washer, nut, and bolt or lag screw should be manufactured from the same metal.

Corrosion in Preservative-Treated Wood

Oil-type preservatives. Corrosion of metals in wood treated with oil-type preservatives is usually not a problem because the presence of heavy oils tends to inhibit corrosion. This is especially true in construction situations in which the holes for the fasteners are bored prior to treating.

When the preservative has not penetrated to the center of the wood member, such as in large beams or posts, fasteners are driven into moist, untreated wood, and fastener corrosion can occur.

Waterborne preservatives. Waterborne preservatives that contain copper cause corrosion of some metals. Corrosion in moist copper-treated wood is directly related to the presence of copper ions because they will "plate out" on a fastener that is more electronegative than copper. When this happens, a galvanic corrosion cell consisting of the fastener and the deposited copper is formed and the fastener corrodes (Baker,1988).

Geographic Location

Because a variety of climates and exposure conditions exist, local conditions should dictate proper fastener selection. In the United States, climates range from subtropical to desert to arctic. This has a large effect on the corrosion rates of metal fasteners in wood. Where the climate is moist and warm, corrosion rates are the highest; where it is cold and/or dry, corrosion rates are the lowest. The corrosion rates can differ by a factor of five to ten.

The average outdoor humidity in North America varies depending on location and season. In areas of higher average humidity and warmer temperatures (e.g., the southeastern United States, portions of the Midwest, and along the coasts), the hazard of fastener corrosion (and wood decay-fungi attack) is greatest. Even in dry areas of the country, an outdoor structure that is very near or over water, or for some reason is wetted much of the time, can have a high moisture content, thus promoting corrosion and decay.

Recommended Fasteners and Hardware

For treated or untreated wood that is above grade in structures exposed to weather, we suggest hot-dipped galvanized steel fasteners with at least 0.85 oz of zinc per ft^2 (259 g/m^2). This recommendation also applies for hardware used within the structure (joist hangers, straps). For wood that is below grade and treated with a preservative that contains copper, or that is in contact with saltwater, we suggest the use of AISI stainless steel Type 304, copper, or silicon bronze. Note that engineering design values are not published for copper and silicon bronze.

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Wood Design Focus

A Newsletter of Contemporary Wood Engineering

Volume 4, Number 3 Fall 1993

This Issue: Design for Exterior Exposure