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Combining hygrothermal and corrosion models to predict corrosion of metal fasteners embedded in wood

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A combined heat, moisture, and corrosion model is presented and used to simulate the corrosion of metal fasteners embedded in solid wood exposed to the exterior environment. First, the moisture content and temperature at the wood/fastener interface is determined at each time step. Then, the amount of corrosion is determined spatially using an empirical corrosion rate model and the inputs of the first step. The result is a corrosion profile along the length of the fastener generated by summing the corrosion depths determined at each time step. We apply the combined model to predict the annual corrosion depth along a metal fastener in wood decks situated in nine different US cities. Corrosion profiles are found to exhibit the same general shape independently of climatic load, with the largest amount of corrosion occurring at 1–5 mm from the wood surface with corrosion depths ranging from 5 μm in Phoenix, Arizona to 45 μm in Hilo, Hawaii. Corrosion is confined to the first 7–20 mm of the fastener below the wood surface. By varying the climatic loads, we find that although there is a definite relation between total annual rain and total annual corrosion, under the same rain loads corrosion is higher for a climate with more evenly distributed rain events. The proposed combined model is able to capture corrosion behavior under varying loading. A sensitivity analysis gives guidelines for future corrosion modeling work for fasteners in wood.

1. Introduction

Wood structures that are exposed to the exterior environment, like terrace decks, balconies, playground equipment, etc., are susceptible to moisture damage such as wood rot and metal corrosion. Frequently, softwoods (pine, spruce) are treated with wood preservatives to be durable and suitable for these exterior applications. The durability of treated wood depends not only on protecting the wood from biological attack but also on minimizing the corrosion of embedded fasteners. The corrosion rate of embedded fasteners depends on the moisture and temperature conditions at the metallic surface, which fluctuate considerably in outdoor wood constructions considered here. In this paper, we present a modeling approach that combines heat and mass transport in the wood exposed to environmental loading with corrosion of the metallic fasteners in contact with the wood.

The specific context of this paper stems from a wood preservation regulation change that occurred in the United States in January 2004. Alkaline copper quaternary (ACQ) and copper azole (CuAz) replaced chromated copper arsenate (CCA) in residential applications [1]. These alternative wood preservatives were suspected to be more corrosive to embedded metal fasteners than CCA [2,3]. Since the regulation change, the corrosiveness of CuAz and ACQ has been evaluated in several laboratory tests. Most of this work used the American Wood Protection Association AWPA E-12 standard, which places metal coupons between blocks of wood at 49 °C and 90% relative humidity (RH) for at least 240 h [4,5]. Other procedures using more realistic temperatures were developed. Kear et al. [5] exposed fasteners embedded in treated wood at 21 °C to 3 different relative humidities ranging from 75% to 98% RH for 1 year. Zelinka and Rammer [6] embedded fasteners in blocks of treated wood exposing them to 27 °C and 100% RH for one year. Furthermore, electrochemical tests in a water-extract of treated wood were found to have the same corrosion rates as those measured at the 27 °C 100% RH conditions [7]. These tests all show that ACQ and CuAz are more corrosive than CCA. However, due mainly to the variations of testing conditions, the measured corrosion rates from these tests have a wide range of values, for example, from 2 to113 μm yr^{-1} for hot-dip galvanized steel in ACQ-treated wood (1–26 μm yr^{-1} for CCA). As the corrosion rate of

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