Avast Ye Salty Dogs: Salt Damage in the Context of Coastal Residential Construction and Historical Maritime Timbers

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ABSTRACT

Salt damage is a frequent problem in wood exposed to seawater and other saline environments. Symptoms of salt damage are often referred to as fuzzy wood and have been historically considered non-structural damage, but a growing number of customer inquiries have prompted a re-evaluation of this phenomenon. This paper details several case studies involving salt damage, discusses current knowledge on the underlying mechanisms and highlights on-going work at the Forest Products Laboratory to investigate the causes and effects of salt on wood. A better understanding of the salt damage process will eventually lead to remedial treatment options.

Keywords: Salt damage, tracheid defibration, coastal construction, historic ships, wood preservation.

INTRODUCTION

Salt damage, otherwise known as salt kill, tracheid defibration or "fuzzy wood," is a frequent problem in wood exposed to seawater or other saline environments (road salts, brine or fire retardants). Symptoms of salt damage are often referred to as fuzzy wood due to the separation of fiber tracheids on the outer affected surface. Past studies have shown that salt damage is a slow and gradual process that should not impact the useful service life of the product. However, increasing consumer inquiries about salt damaged wood have prompted further investigation of this issue.

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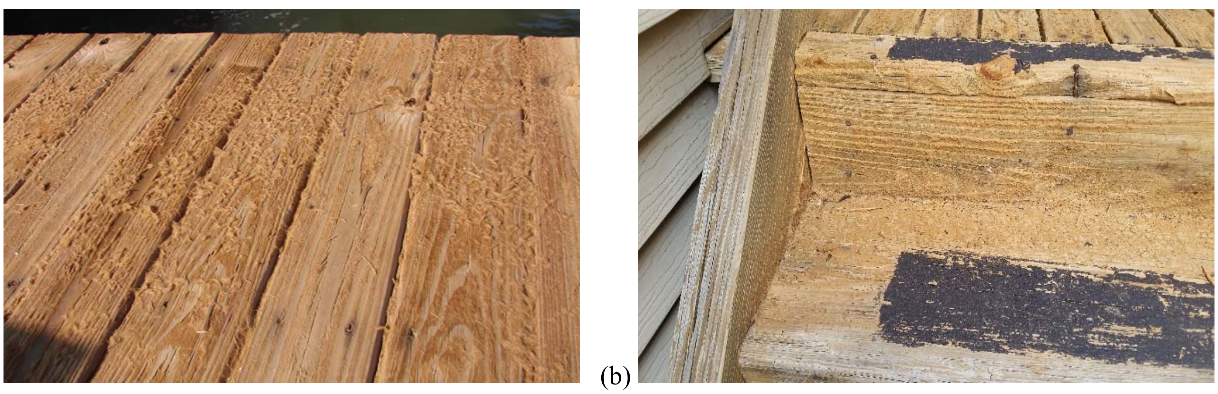

Figure 1: Characteristic damage to treated wood caused by salt. (a) Treated deck boards exposed to frequent wetting of saltwater develop a fuzzy appearance. (b) Excessive use of de-icing salts can also cause salt damage as evidenced on these stair treads.

The issue of salt damage is not new to the wood protection industry and has always been treated as a curiosity that can frequently be seen on wood in and around coastal areas, as well as non-coastal areas through contact of wood with deicing salts (Figure 1). Parameswaran [1] detailed observations of defibered wood in potash storage areas, which typically have a very high pH. Their study attributed much of the damage to alkaline pulping of the middle lamella. Johnson and Ibach [2] studied fiber tracheid separation and found that they could create the phenomenon in the lab after 100 repeated wetting cycles with a saturated salt solution. In their discussion, they attributed salt damage to physical damage to the middle lamella via microchecking. Blanchette and his colleagues have also studied salt damage in Antarctic expedition huts [3] and pueblo houses in the New Mexico desert [4] and attributed salt damage to corrosion of the middle lamella via action of the salt accumulation. The common theme that has been observed in all of these studies is that salt damages the middle lamella and results in tracheid separation.

The following paper serves to summarize the current work being done at the Forest Products Laboratory (FPL) in the area of salt damage, both to diagnose underlying causes as well as provide meaningful recommendations to mitigate the damage.

SELECTED CASE STUDIES FROM FPL

Charleston study

In 2012, samples from 26 piles in and around the port of Charleston were sent to FPL from Jim Healey at Cox Industries [5]. The samples in question had varying degrees of salt defibration (Fig. 2) and it was suggested by a third party that the condition of these pilings was due to the presence of a copper tolerant decay fungus.

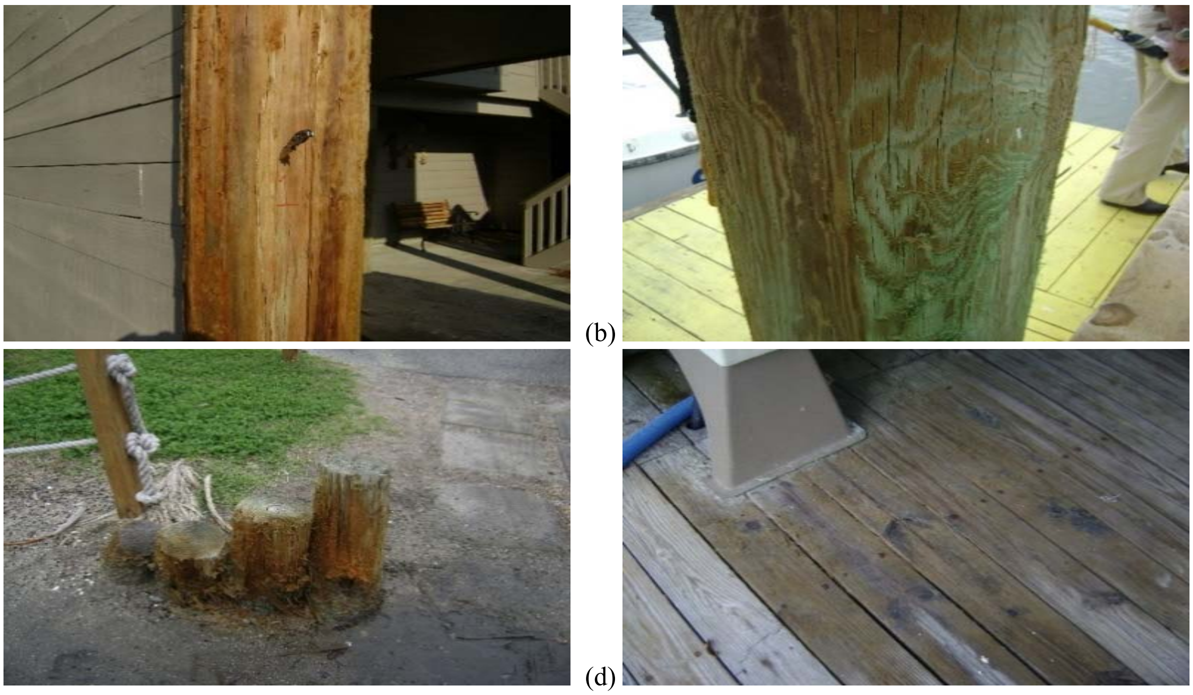
(a) (b) (c) (d)

Figure 2: Images from Charleston, SC depicting various instances where salt damage was found: (a) foundation pilings of a condominium installed into the salty water table, (b) marine pilings, (c) terrestrial piles with butt ends sitting in salty water table, and (d) treated deck boards exposed to constant wetting with seawater.

The samples were analyzed for pH (Fig. 3) and microscopically for fungal presence using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) for elemental analysis (Fig. 4). Results indicated that the pH ranged from 5-7 and there was no presence of fungal hyphae other than a few sap stain fungi that do not impact wood strength. The pH range was much too high for brown rotted wood, which is normally in the 2-3 range due to production of organic acids by the fungi [6]. In addition, none of the samples had any symptoms of brown rot decay, which is typically characterized by a rusty brown cross checked surface.

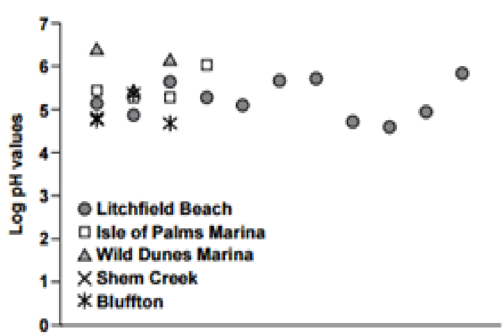

Figure 3: pH values for wood samples received from Charleston.

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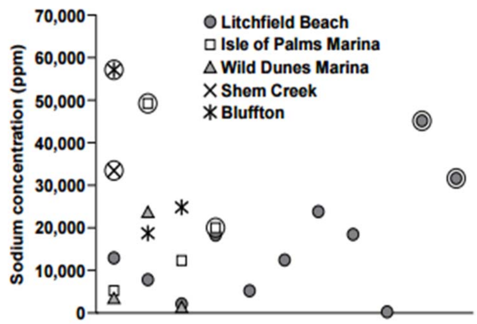

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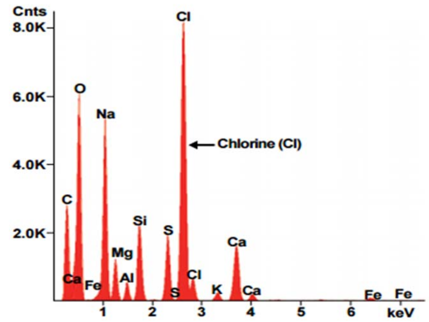

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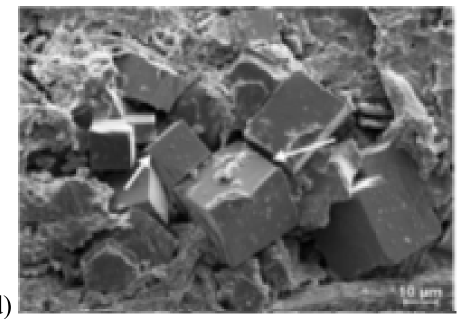


Figure 4: (a) Results of salt concentrations of samples in ppm determined by ICP-OES. (b) Example EDAX output showing high adundances of Na and Cl within the samples. (c) SEM images showing defibered wood; note removal of surrounding lignin matrix (middle lamella), leaving only residual tracheid cells. (d) Large cubical NaCl (halite) crystals found in and around wood surfaces of fuzzy wood samples.

Preservative retentions were also analyzed using inductively coupled plasma atomic emission spectroscopy (ICP-OES), and measured retentions were well within expected values for poles of their class and age. It was concluded that the damage observed on these pilings was indeed due to the actions of salt and not a decay fungus. In attention to the general technical report, an FPL TechLine differentiating salt damage from biological degradation was published [7] in order to provide end users better information on this matter. Additionally, a separate technical report was issued by Mississippi State University (MSU) with similar information [8]. As a result of the information provided by both FPL and MSU, the frequency of reports of salt damaged wood has increased.

Coastal Florida

In the fall of 2014, FPL received several data calls from condo owners in and around ocean front properties in Florida that had extensive salt damage on the surface of foundation piles that were enclosed with stud walls and sheathing to create a garage. The salt water was wicking up through the piling from the water table and the customers indicated moisture problems as well as corrosion to fasteners in the vicinity of the salt damage. Photos that highlight the damage are shown in Figure 5.

Figure 5: Residential damage due to salt. These are foundation piles placed into a high salt water table. The saltwater has wicked through the wood causing fuzziness and corrosion. The image on the right also had extensive water damage as it was encased in drywall.

Additionally, marina owners in coastal Florida have submitted questions about salt damage occurring on wood being used as decking and a bulkhead in a marina. The salt damage was not as extensive as what is typically seen in a covered exposure, but the damage was severe enough to prompt its replacement, for which a wood plastic composite (WPC) was being considered. There are some limited literatures on the effects of salt damage on WPCs, but the damage is fundamentally different [9].

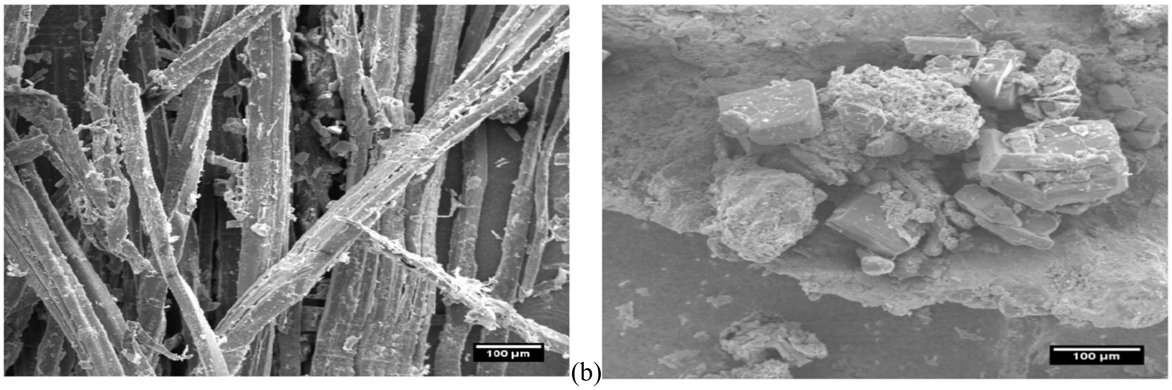
Figure 6: Treated deck boards, approximately 5 years old with severe salt damage. Marina owners were concerned that this was not safe for foot traffic. Additionally, a nearby marine treated bulkhead (not pictured) had extensive damage and was scheduled to be replaced with a composite product.

The Eureka

The National Park Service contacted FPL in the spring of 2015 to discuss on-going renovations to a wooden ferry, the *Eureka*, located at the Maritime National Historical Park in San Francisco, CA. On-site inspections were made by FPL staff, and it was determined that excess moisture was a key contributor to the problem. Salt damage was noted throughout the holds and corrosion was also apparent. Salt damage was severe enough to warrant failure of vertical beams within the rear hold (Figure 7).

Figure 7: Compressively failed Douglas-fir posts with severe salt damage. White posts were installed 5 years ago to help support the failing members. This is the first structural failure of salt damaged wood documented by FPL.

In addition to the excessive amount of visible salt defibration, corrosion was present on almost all of the iron fasteners embedded into the timbers. Samples were taken in the hold of the *Eureka* and subjected to elemental, microscopic and mechanical testing. Elemental characterization using energy-dispersive X-ray spectroscopy (EDS) indicated high levels of Na and Cl as noted in the Charleston study. Scanning electron microscopy (SEM) revealed fiber separation consistent with salt damage and presence of large cubical crystal deposits indicative of the rock salt crystal structure (Figure 8).



(a) (b)

Figure 8: SEM micrographs of (a) defibered wood found throughout the hold of the Eureka and (b) corrosion products found on the surface of the wettest timbers in the hold. SEM micrographs created by Tom Kuster, USDA-FS, Retired.

CURRENT RESEARCH UNDERWAY AT FPL

Remediation of the 'Eureka'

Following our initial observations of the *Eureka*, moisture monitors have been placed throughout the two holds that exhibited the highest concentration of salt damage. Temperature fluctuations, percent moisture content and relative humidity (RH) within the holds are being monitored to gather baseline data on the moisture dynamics. A key underlying condition in the *Eureka* is that of excessive moisture, which has been shown to be a key driver of salt migration in comparable materials [10]. By controlling moisture levels in the hold of the ship, it should be possible to slow the capillary migration of the salt. A secondary objective is to evaluate suitable coatings that can be used to remedially repair damaged surfaces. Typically, paints and sealants fail to adhere to the damaged surface and the salt will continue to disrupt wood from underneath the coating.

Salt chamber

In the summer of 2015, a decommissioned test apparatus (Figure 9) was acquired from Princeton University professor George Shearer, who had been using the chamber to study salt efflorescence in concrete and stone [11], which have similar infiltration patterns to wood. This chamber is currently being used at FPL to create salt damage in a controlled manner to study material properties in both unaffected and salt damaged wood.

Figure 9: Test chamber used to test effects of salt on limestone and cement. Photo used with permission from Scherer et al. 2002. The same chamber is now being used at FPL to test the effects of salt on wood in a similar manner.

Strength testing of salt damaged wood

Several 2x2 Douglas-fir rails that were used to keep rock salt in place were found in the hold of the *Eureka*; these had varying levels of salt defibration, heavy corrosion, and were water soaked. These rails were tested at FPL using Janka hardness as an indicator of strength reduction. Bending strength was not evaluated as the Douglas-fir sections were not large enough to conduct ASTM E445 tests [13]. Results of the hardness test indicated that, compared to sound Douglas-fir sapwood, the Janka hardness was reduced by approximately 25-30%. Preliminary results of the hardness tests conducted at FPL are presented in Figure 10. Prior literature does not address any mechanical impacts to wood as a result of salt damage. However, Schneider et al. 1997 [12] studied long term storage of Douglas-fir poles in the Great Salt Lake and found minimal strength degrade as a result. This is not to say that salt damage does not impact wood, only that wood soaking in salt water for an extended time does not cause strength loss. The actual extent of salt damage occurs as wood wicks saturated salt water up through the piling and the salt crystals are re-deposited as the moisture exits the wood via evaporation. The concentration of salt crystals at the evaporative interface is where the defibration occurs, therefore, contact with salt water is not solely what causes the damage. Additional testing is necessary to determine the extent and exact location of strength degrade due to salt damage.

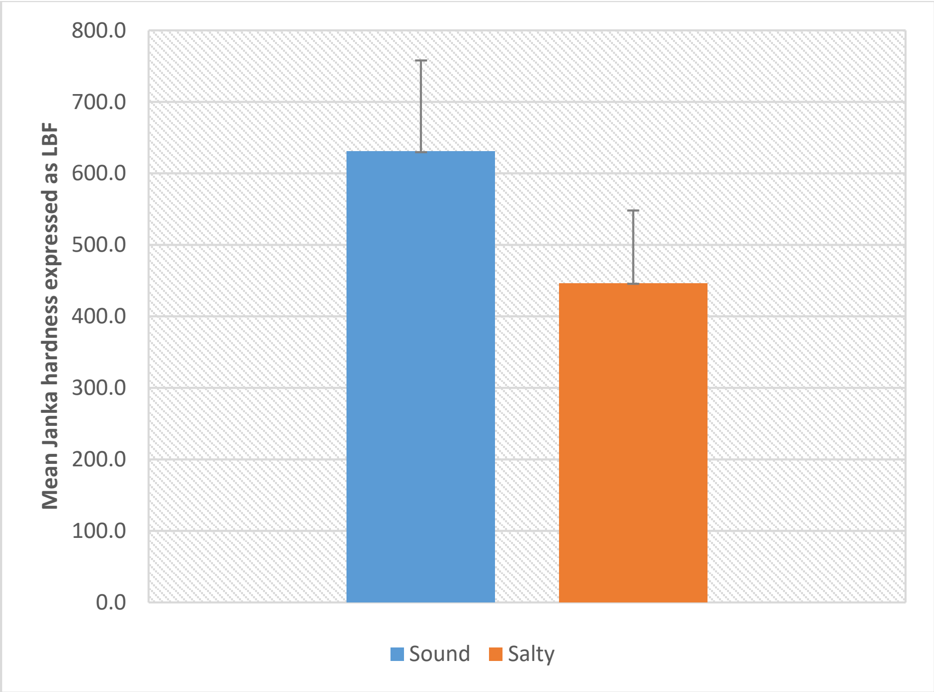


Figure 10: Preliminary results of Janka hardness testing of Douglas-fir rails from the hold of the *Eureka* (orange column) compared to control Douglas-fir in sound condition (blue column). Tests were conducted with a 2mm ball on all four faces of the rails. Janka units are reported in pounds-force (LBF). Published values for Janka hardness of sound Douglas-fir are 660 lbf.

DISCUSSION

Salt damage is a problem that has grown in visibility to the consumer. Frequent calls and a lack of useful recommendations have prompted FPL to re-evaluate this phenomenon. It is increasingly clear that frequent exposure to salt water in both untreated and treated wood can lead to tracheid separation. Ongoing research will determine the extent of damage that salt exhibits on wood and explore possible remedial options.

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DISCLAIMER

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