THE VULNERABILITY OF ROTTING MARINE STRUCTURES TO IGNITION BY DISCARDED CIGARETTES (THE 2003 SATURNA ISLAND WHARF FIRE)

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ABSTRACT

This project studied the vulnerability of rotting marine structures (such as wharves and docks) to ignition by discarded cigarettes. The phenomenon of rotting wood was examined in detail, and related to the manner in which creosoted piles rot. Several informal tests demonstrated the ignition mechanism of rotting wood by an ignited cigarette. A series of tests determined the moisture content (MC) below which rotten Douglas Fir (also called Douglas tree and Oregon pine; genus Pseudotsuga menziesii) ignites and smoulders. Another series of tests determined the rate at which creosoted Douglas Fir piles used for docks and wharves dry to the point at which they are ignitable by cigarettes. Historical records were consulted to determine the amount of rainfall before the fire. By comparison of the two studies, the moisture content of creosoted piles in a marine structure was estimated and a timeline towards ignitability was determined. A third set of four concurrent tests used cigarettes to ignite rotten wood in exemplar test piles which smouldered and then transitioned into flaming combustion. The process was witnessed and photographed in detail. The results informed the likelihood of ignition by cigarette of a particular wharf structure in 2003, and other structures of similar construction. The likelihood of fires of similar origin was considered, and means to prevent them is discussed.

INTRODUCTION

Figure 1

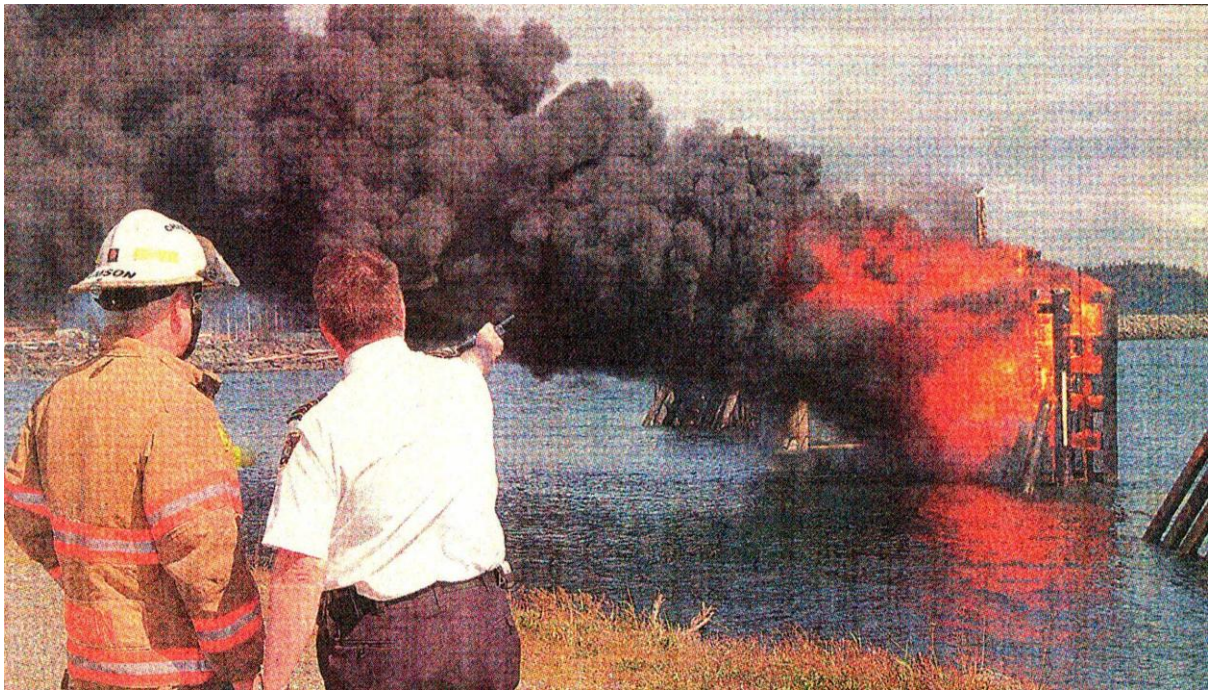
A large fire consumed most of the Saturna Island wharf and the neighboring BC Ferries waiting room on June 5 of 2003 (Figure 1). The fire was witnessed by several patrons of a nearby pub. The intensity of the fire presented difficulties for the local fire fighters, since the wharf was constructed of creosote saturated wood and the fire was beneath the structure.

Investigators were hired to determine the cause of the fire. One investigation firm determined that the fire started under the waiting room floor and "an electrical wiring failure is the only plausible scenario for a fire to occur at that location, and the correct parameters were present to permit initiation." A second investigation firm determined that the fire started outside of the waiting room, and "the only known possible source of ignition under the BC Ferry wharf was electrical energy circuits ..." The same firm also stated, "ignition to the pylons or main support beams would be extremely difficult thereby limiting the possible sources of ignition ..."

A third investigation firm determined that the cause of the fire was "undetermined."

It appeared to all investigators and witnesses that the fire started beneath the decking of the wharf or the floor of the waiting room.

Figure 2



Another fire was reported at 11:15 a.m. on April 23 of 2007, at the Campbell River ferry dock that services the Quadra Island ferry (Figure 2). The fire occurred at a 'dolphin', a marine structure consisting of wooden piles driven into the ocean floor. This dolphin did not contain any electrical wiring, so an electrical cause was not possible.

Both fires occurred in an area where discarded cigarettes were likely to be found. The Saturna Island wharf is situated beside a fuelling station where smoking was forbidden, and also adjacent to the waiting room where "no smoking" signs were displayed. Also, the nearby pub did not allow smoking. However, smoking was permitted on the wharf. When the ferry was in dock, the Campbell River ferry dock dolphin was situated alongside the ferry, and smoking was not permitted inside the ferry. Passengers who smoked would therefore typically smoke on the ferry deck and discard their cigarettes over the side before they disembarked when the ferry docked.

A study was undertaken to determine the likelihood of ignition of rotten wood by a discarded cigarette.

BACKGROUND: DISCUSSION ON ROTTING OF WOOD

Wood decays as a result of a fungal growth in the wood tissue. The fungal growth occurs when wood reaches at least 35 to 40 percent moisture content; there is some supply of oxygen, and temperatures are above freezing (ideally between approximately 18 to 32°C and less than 38°C). There are two types of rot, often referred to as brown rot and white rot. Most rot found in marine structures is brown rot.

Marine piles normally consist of entire tree trunks which are driven into the ocean floor, tip down. The centre of these piles, or the heart wood, is the most vulnerable to rotting, leaving a bowl shaped depression that tends to retain the rotten wood in place.

Wood consists of both lignin and cellulose. Brown rot consumes the cellulose, leaving the wood weakened and brown in colour due to the remaining lignin. It is the remaining brown lignin that is the focus of the study of this paper, particularly because of its tendency to smoulder. [i]

INFORMAL TESTING OF IGNITION OF ROTTEN WOOD

Figure 3

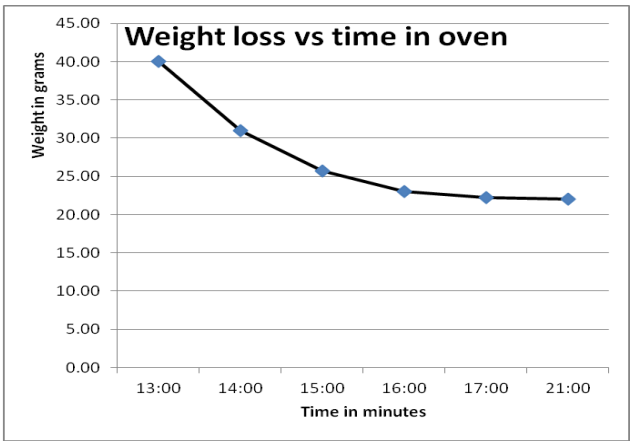
Many informal tests were carried out to determine whether it is possible to ignite rotten wood with a discarded cigarette. In several tests of a rotten beam it was noted that ignition was possible and frequent, but that the smouldering ceased after a period of time, presumably when suitably rotten material had run out, or when high humidity did not permit smouldering (Figure 3). There was no determination made of the wood's humidity levels. It was noted that in cases where ignition of the rotten wood was possible it occurred very quickly, almost as quickly as the time it would take to burn one's hand if a cigarette was placed in it. Therefore it is unlikely that fire safe cigarettes would change the results of the following tests (although this was not specifically tested).

It was noted that the presence of wind increased the likelihood of ignition of a smouldering fire by a cigarette, and increased the rate of smouldering. All of the following tests (with the notable exception of the final test) were done under conditions without wind.

Tests of sound wood revealed that, typically, only a burn mark remained after exposure to a cigarette. Although attempts to ignite saw dust - even when bone dry - did not result in smouldering. I am aware that in some cases it is possible. Since the testing thus far proved that cigarettes could ignite rotten wood (but not sound wood or saw dust), further analysis focused on the factors that impact the ignition of rotten wood.

TEST TO DETERMINE THE LENGTH OF TIME REQUIRED TO REDUCE THE MOISTURE CONTENT IN ROTTEN WOOD SAMPLES

Figure 4



The moisture content (MC) in percent is defined as:

$$MC\ (\%) = \frac{(\text{wet weight} - \text{dry weight}) \times 100}{\text{dry weight}} \quad [1]$$

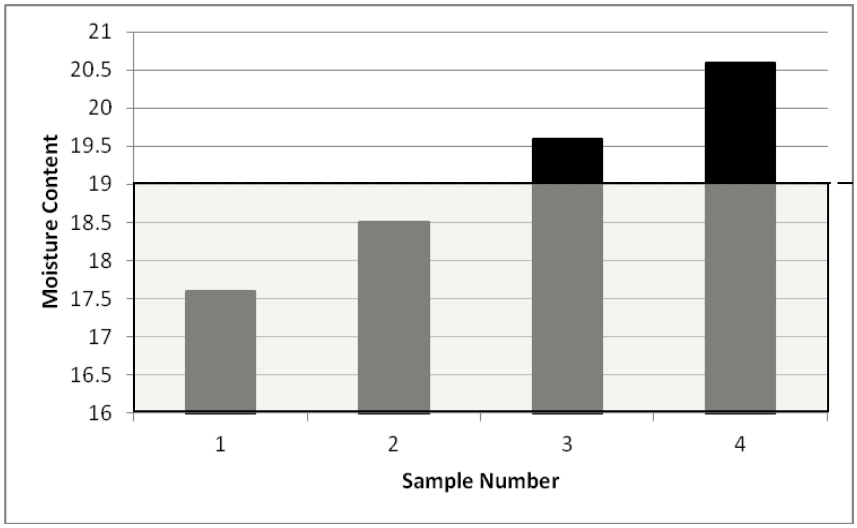
For the purpose of this test, the drying of rotten wood samples was done in a 100°C oven with air movement. The temperature was measured by placing the bulb of an alcohol glass

thermometer in the oven and the scale on the outside. The weight was measured in still air with a scale accurate to 0.01 grams. Repeated experiments on samples of rotten wood indicated that with the equipment used, the accuracy of the measurements was + or – 0.2% for a sample size of approximately 15 grams.

The moisture content and weight of a standard envelope No. 10 (105 mm by 245 mm) was measured and accounted for in the calculations. Samples of 20 to 40 grams of wood were put in the envelopes and the moisture content was measured after every minute. The weight stabilized after approximately 8 minutes. Consequently, a time of 10 minutes for drying the samples was used in all cases (Figure 4).

TEST TO DETERMINE THE LEVEL OF MOISURE CONTENT THAT PERMITS SMOULDERING

Figure 5



Differing levels of moisture content were obtained by dividing a large sample of rotten wood of Douglas Fir that was known to have a moisture content that allowed smouldering into four bags, and adding different amounts of water to the bags before sealing them. The bags were left for four months to allow the moisture content to spread uniformly across each sample.

Testing showed that samples of well rotted wood with a moisture content of 19.6% and 20.6 % would ignite but not continue smouldering in still air. However, samples with moisture contents of 18.5% and 17.5% would ignite and smoulder until completely consumed. Therefore, for rotten wood from Douglas Fir to ignite and smoulder unassisted in still air, the moisture content must be approximatley 19% or lower (Figure 5).

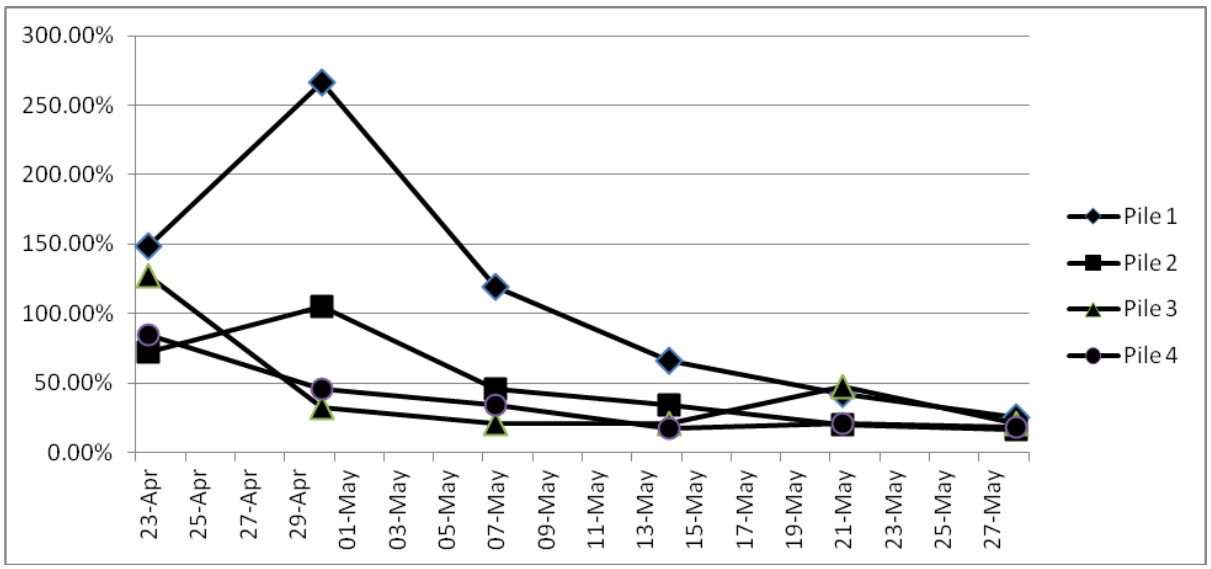
TEST TO DETERMINE THE LENGH OF TIME FOR A ROTTEN MARINE PILE TO REACH A MOISTURE CONTENT LEVEL THAT SUSTAINS SMOULDERING.

Four creosoted Douglas Fir pile tops were obtained for this experiment. Three came from Salt Spring Island, and one came from a Vancouver wharf. Each displayed advanced rot in its centre, and a remaining wall around the outside. The rotten wood in the pile tops was left there for the experiments. All of the pile tops were left out in heavy rain and became thoroughly moist. Pile numbers 1 and 2 were left outside but covered after April 30 (to allow partial exposure to wind but to prevent rain exposure from adding to the humidity). Pile numbers 3 and 4 were taken indoors and set

beside a dehumidifier. The rotten wood used for testing the moisture content was returned to the pile top that it had originated from.

The moisture content of all four piles decreased at a similar rate. At the end of one month, the average moisture content of the piles was approximately 19%. The piles housed indoors and placed beside a de-humidifier dried at approximately the same rate as the piles left outdoors and in ambient wind conditions. Therefore, after saturation with water, rotten wood in marine pile tops reaches a moisture content level conducive to smouldering after approximately one month without rain (Figure 6).

Figure 6



The irregularity is due to moisture content differences in the pile tops. The rotten wood closest to the top tended to be the driest.

TEST TO DEMONSTRATE THE LIKELIHOOD OF IGNITION OF PILE TOPS BY CIGARETTES

The four pile tops were taken to an area close to the Number 9 Fire Hall in Surrey, BC. The test was witnessed by many members of the fire hall. Three lit cigarettes were placed in the rotten wood in each of the four pile tops at approximately 9:45 a.m. At approximately 10:00 a.m. three of the four pile tops were noticeably smoking, and one transitioned from smouldering combustion to flaming combustion. At 10:19 a.m., the second of the four pile tops transitioned from smouldering combustion to flaming combustion. At 10:23 the third pile transitioned from smouldering to flaming combustion, and then returned to a smouldering condition. At 11:06, the fourth pile transitioned from smouldering to flaming combustion. At 11:20, the fires were extinguished. Therefore, in all four cases, cigarettes established smouldering combustion in the pile tops. The time taken for smouldering combustion to transition into flaming combustion in the four pile tops was 15 minutes, 34 minutes, 38 minutes, and 81 minutes. The variation in times is related to the distance from the point of origin of the smouldering to the pile top wall where a vertical surface allowed the transition from smouldering combustion to flaming combustion (Figure 7).

Figure 7

DID THE FIRE AT THE SATURNA WHARF START BECAUSE OF A CIGARETTE?

The likelihood that the Saturna Island Wharf fire was started by a cigarette that accidentally landed in a pile top is supported by a number of factors:

- Several pile tops under the Saturna Island Wharf lacked a metal cover (called a “hat”) and had been abandoned and not removed.

- Many of these piles evidenced centre rot and creosoted sides so that the rotten wood was retained in the bowl formed by the outside of the pile.
- Weather records indicated that there had been no precipitation in the area for the ten days preceding the fire, and only small amounts of precipitation before that for a total of 19 mm of precipitation for the month before the fire. The ambient maximum temperature on the five days before the fire rose from 17°C to 29°C.
- Smoking was permitted on the Saturna Island Wharf, and the wharf was the only convenient place in the area to smoke.
- Photographs and char analysis indicated that the fire started under the wharf, and was blown sideways and under the nearby waiting room by the wind.
- There was no wiring under the wharf but some wiring under the waiting room.

SUMMARY

Both the Saturna Island wharf fire in June of 2003 and the Campbell River ferry dock fire in April of 2007 were likely caused by a cigarette that dropped on rotten wood. Marine piles are particularly vulnerable to ignition by a cigarette because:

- Wood rots with exposure to moisture;
- Marine piles consist of entire tree trunks which typically rot at the centre leaving a bowl shape to retain the rotten wood;
- A moisture content of 19% or lower allows rotten wood to smoulder until suitable geometry enables the fire to change from smouldering combustion to flaming combustion;
- The addition of creosote to inhibit rot will act as an accelerant to the fire.

FIRE PREVENTION METHODS

The most effective method to prevent fires from cigarettes contacting rotten wood on marine structures is to provide all piles with a metal hat to cover the top of the pile. The hat would tend to prevent rot and would act as a barrier to discarded cigarettes. Also, abandoned piles should be removed as they are not only a fire hazard but also cause damage when they break free. Piles made of non flammable materials should be considered for new construction to prevent fires and also to prevent marine pollution due to the creosote. Provision of fire-safe locations for smokers could be an option and smoking on marine structures made of wood should be discouraged.

CREDITS

J Edward Gouge, QC, Ministry of Attorney General, Legal Services Branch, Victoria, BC for funding much of the research

Al Winning, former Director, Terminal Maintenance, BC Ferry Corporation, Sidney, BC, for information regarding the construction of marine structures

Deputy Chief Gordon Anderson and the members of No 9 fire hall in Surrey BC for providing the site and safety services of the final test

[i] Baker, M C, National Research Council Canada, CBD-111 Decay of Wood, originally published March 1969