Visual and Nondestructive Evaluation of Red Pines Supporting a Ropes Course in the USFS Nesbit Lake Camp, Sidnaw, Michigan

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Project Description

On Wednesday, September 13, 2006 through Friday, September 15, 2006, forestry scientists from Michigan Technological University and their cooperators conducted decay detection tests on 10 red pines supporting a ropes course in the United States Forest Service (USFS) Nesbit Lake Camp in Sidnaw, Michigan. The Copper CountIy Intermediate School District (CCISD), Hancock, Michigan, cooperated with the USFS in providing the recreational ropes course for use by students and other groups. The purpose of the project, in addition to detecting decay, was to research the reliability of detection protocols and to compare results of the various equipment used. The research team and others present were:

- John Forsman, Assistant Scientist, School of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI
- John Erickson, Retired Director of the USDA Forest Products Laboratory and Research Scientist at Michigan Technological University, Houghton, MI
- Robert Ross, Project Leader, USDA Forest Products Laboratory, Madison, WI
- Brian K. Brashaw, Program Director, Natural Resources Research Institute (NRRI), University of Minnesota Duluth, Duluth, MN
- Xiping Wang, Senior Research Associate, Natural Resources Research Institute (NRRI), University of Minnesota Duluth, stationed at the USDA Forest Products Laboratory, Madison, WI
- Bob Vatalaro, Principal Research Shop Foreman, NRRI, University of Minnesota Duluth, Duluth, MN
- R. Bruce Allison, Registered Consulting Arborist, Allison Tree Care Inc., Madison, WI
- Shanqing Liang, Visiting Graduate Student, Chinese Academy of Forestry, Beijing, China, Intern at the USDA Forest Products Laboratory
- Stephen Schmieding, Photographer, USDA Forest Products Laboratory, Madison, WI and
- Kenneth Maki, CCISD, Hancock, MI.

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Equipment and Methods

Measurement and visual assessment tools consisted of a steel tape measurer, a rubber sounding mallet, binoculars, and a hand trowel. Decay detection tools used were the Fakopp Microsecond Timer, the Fakopp 2D Acoustic Tomograph, the PiCUS Sonic Tomograph with the PiCUS electronic caliper, and the IML400SE Resistograph.

A map was created assigning identification numbers 1 through 10 for the 10 red pines supporting the ropes course. The simpler tests were used to select those trees with higher probability of internal structural defects for further investigation with the more time consuming tests. This multiple test decay detection protocol was as follows:

1. A visual tree assessment test (Mattheck and Breloer 1994, Metheny and Clark 1994, Pokorny 2003) using visual signs and symptoms of tree decay screened for suspect trees.
2. A single path stress wave test using the Fakopp Microsecond Timer was used to screen for probable defective trees. Multiple cross-sectional elevations were selected including all elevations near cable and platform attachments.
3. A multi-path stress wave tomography test using PiCUS Sonic Tomograph and electronic calipers conducted on those trees and elevations identified as suspect by the screening test.
4. A parallel multi-path sonic wave test using the Fakopp 2D Acoustic Tomograph.
5. A resistance micro-drill test using an IML400SE Resistograph conducted at critical areas identified in prior testing.

Tests and Observations

1. The visual examination conducted by Allison and Liang screened for root plate decay by noting abnormal trunk taper near ground level, poorly defined buttress roots and valleys, and fungal conks. Trunk decay was screened by looking for cavities, cracks, bulging, and seams. Crown decay was observed as dead branches or die back at the apical leader. The general health of the tree, as expressed by needle color, size, and distribution, was used as an indicator of decay in the root plate, trunk, or crown.
2. Forsman and Vatalaro used the Fakopp Microsecond Tuner on all 10 trees at various cross-sectional elevations. Two passes were taken at each cross section, one from north to south and one from east to west. Higher elevations were reached using a rented mechanical aerial lift platform. A threshold velocity of 300 usec per foot was used to differentiate between wood quality. A reading of less than 300 usec per foot was considered sound wood. Readings above 300 usee per foot were considered indications of decay or defect. The higher the reading, the lower the sound wave velocity, the more serious the probable defect. Of those trunk areas with measured stress wave velocities. those with values 10 percent below expected velocities were selected for further examination.
3. The PiCUS Sonic Tomograph test was conducted on three trees identified as suspect by the screening test (1, 7, and 8). The tests were conducted by Wang, Allison, and Liang.
4. The Fakopp 2D Acoustic Tomograph test was conducted by Forsman on three trees that were identified as suspect by the results of the screening test. The same three trees O, 7, and 8) were selected for testing at similar cross-sectional elevations to allow comparison with results from the PiCUS Sonic Tomograph test.
5. Resistance micro-drill tests were conducted on the three suspect trees. Brashaw conducted three tests on tree 7 selecting sites based on results from the single path stress wave testing. Wang, Allison, and Liang conducted resistance micro-drill tests on trees 1, 7, and 8, selecting sites based on PiCUS Sonic Tomograph imagery (**Table 1**).

Conclusions

Regarding Decay Detection

The single-path acoustic testing revealed three trees with readings beyond the problem threshold. Further testing using the two multi-path tomography tools and the Resistograph on these three trees (1, 7, and 8) confirmed the presence of trunk decay. The methods used are sampling only so one cannot assume decay is absent in other parts of the trees not tested. A precise quantification of decay location and size is beyond the ability of these tools. Combining the tomography with Resistograph tests, however, allows an estimate of the approximate area of decay and an average intact trunk shell in the cross sections tested. Decay in tree no. 1 and tree no. 8 appears localized and below a problem threshold. Decay and defects in tree no. 7 are the most significant of all of the tested trees with both tomography and Resistograph measurements confirming heartwood decay at multiple cross sections at elevations of 10 cm, 50 cm, and 137 cm (**Fig. 1**). It is reasonable to assume the decay is continuous between these tested trunk locations following CODIT decay progression models established by Shigo (1979, 1991). Johnson et al. (2007) state that "a combination of raw data from the IML-Resistograph F300S and a sound knowledge of the principles of the CODIT model allows accurate quantitative prediction of decay in an entire cross section of a tree." **Table 2** shows an estimated percent of decay within each cross section tested with the PiCUS Tomograph on trees no. 1, 7, and 8 and an estimated remaining solid wood shell expressed in both actual size and percent of trunk diameter. Generally accepted thresholds for critical risk of failure are greater that 40 percent cross-sectional area decayed (assuming no cavity opening) and the remaining trunk shell wall less than 15 percent of trunk diameter.

Furthermore, it is reasonable to assume that due to the open wound at the root collar and the visible evidence of carpenter ant colonization, that some level of root decay is present. Even though the visual inspection indicated a normal root collar taper and no evidence of crown die-

Table 1.—*Results of resistance micro-drilling test.*

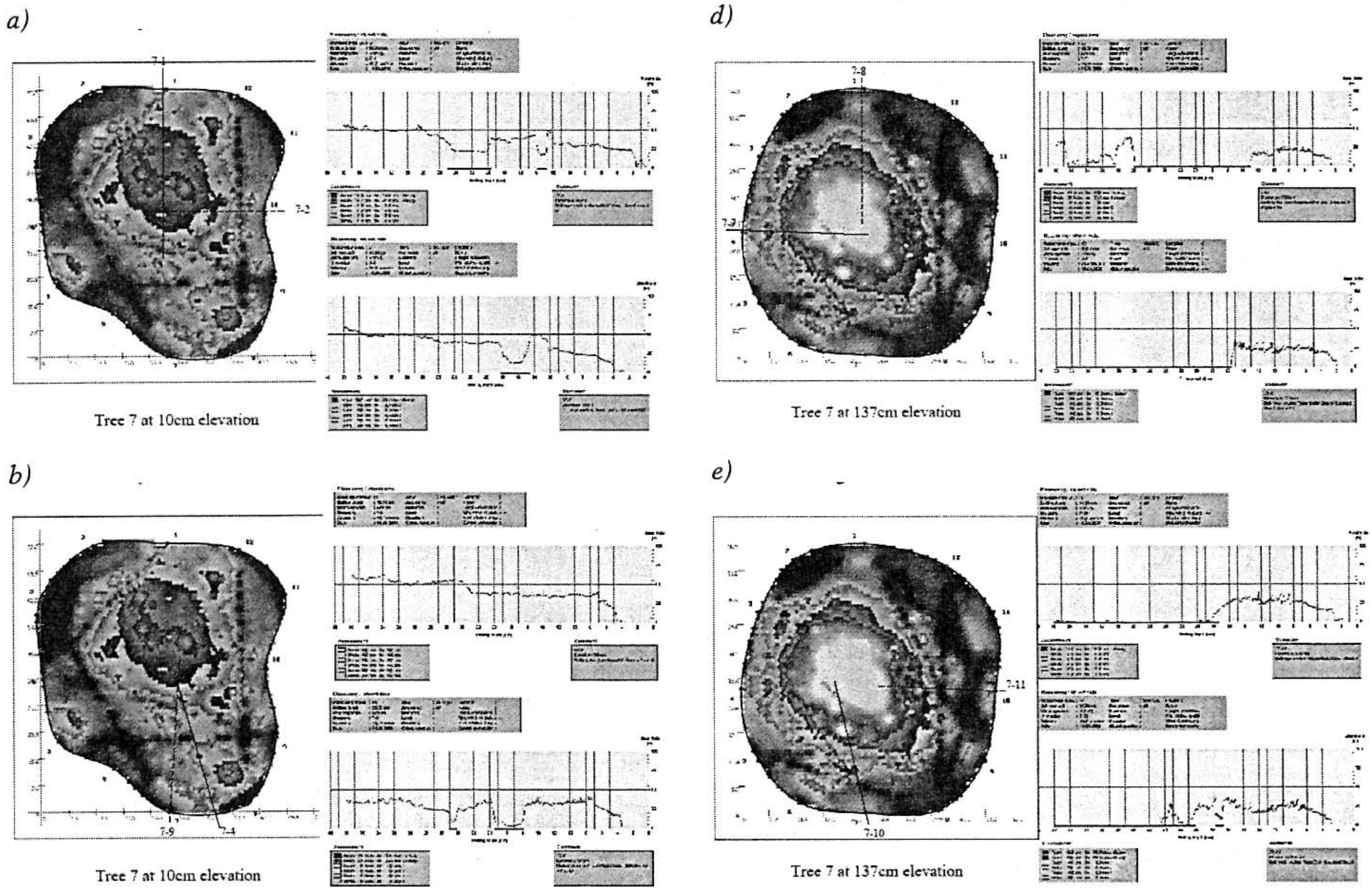
Tree-test #	Elevation	Entry point and location	Trunk diameter at entry point	Comment
	(cm)		(cm)	
1-1	50	From N between 1 and 12 toward S	61	Into crack valley (maybe in and out of crack?)
1-2	50	From NE at 12 toward S at 5	61	Solid
1-3	50	From S at 7 toward N between 1 and 12	61	Toward crack in the opposite direction as 1-1
1-4	50	From E at 10 toward W at 4	61	Decay from 23 to 28 cm and 33 to 38 cm
1-5	100	From E at 10 toward W at 4	61	Decay from 19 cm to 35 cm
1-6	100	From S at 7 toward N between 1 and 12	61	Moderate decay from 25 cm to 38 cm
1-7	90	From W at 4 toward E at 10	61	Solid
1-8	90	From N at 1 toward S at 7	61	Incipient decay at 25 cm depth
7-1	10	From N at 1 toward center and S	80	Isolated decay pockets or cracks: 13 to 14 cm; 20 to 25 cm
7-2	10	From E at 10 toward W	80	Decay pocket or crack: 14.5 to 18.2 cm
7-3	10	From W between 3 and 4	80	Solid
7-4	10	From S between 7 and 8	80	Solid
7-5	50	From N at 1 toward between 7 and 8	71	Decay first third of diameter
7-6	50	From NW at 2 toward between 9 and 10	71	Shows crack at 28 cm depth, consistent with visual position of crack on bark
7-7	135	From W at 4 toward E at 10	60	Severe decay from 13 to 36.5 cm. Shell thickness: 10.5 cm
7-8	135	From N at 1 toward S	60	Severe decay from 15.5 cm to the center. Shell thickness: 13.5 cm
7-9	10	From S at 7 toward N between 1 and 12	80	Tomography shows decay toward W, just missed pocket of decay
7-10	135	From S at 7 toward N at 2	60	Overlapped with test 7-8 in opposite direction: Severe decay from 18 cm to the center and shell thickness: 15 cm
7·11	135	From E at 10 toward W at 4	60	Severe decay starts at 20 cm, extends toward center. Shell thickness: 17 cm
8-1	35	From W between 4 and 5 toward E between 10 and 11	60	Solid
8-2	35	From W/SW at 5 toward NINE at 12	60	Decay pocket from 22 to 30 cm.
8-3	125	From W between 3 and 4 toward E	60	Possible incipient decay from 15.5 to 23 cm
8-4	5	From W at 5 toward E at 12	60	Solid

Note: All of the micro-drilling tests were performed with a drill depth of 40 cm.

back. the exact condition of the structurally important root plate is unknown. Root rot is a major cause of tree failure and is a process that often goes undetected. Shigo (1986) states. 'We know so much less about roots from what we know about the above ground parts of trees. mainly because it takes very hard work to study roots." Nicolatti and Miglietta (1998) in reviewing the advanced tools for measuring decay in tree trunks and limbs note that detecting root rot remains a problem. "Quite apart from this encouraging state of knowledge. however. there still remains the difficulty of monitoring the extent and soundness of a tree's root system. The fall of trees in towns and cities, indeed, is often caused by root rot fungi." Stokes et al. (2002) in reviewing the use of ground penetrating radar to locate and assess roots conclude that. "An efficient and inexpensive method does not yet exist for mapping tree root systems or for identifying the presence of individual large roots."

Regarding Testing Protocols and Equipment Comparison

Resistograph and multi-path tomography confirmed the presence of decay in those trees selected from the single-path screening process. Visual tree assessment also accurately identified those three trees as requiring further study. The PiCUS Sonic Tomograph test with 12 sensors provided higher resolution of decay areas than the Fakopp 2D Microsecond Timer with eight sensors. From a quantitative perspective with approximate location of decay or defect, however, the two tomography tools are well correlated both with each other and the decay location revealed by Resistograph tests. Resistograph testing



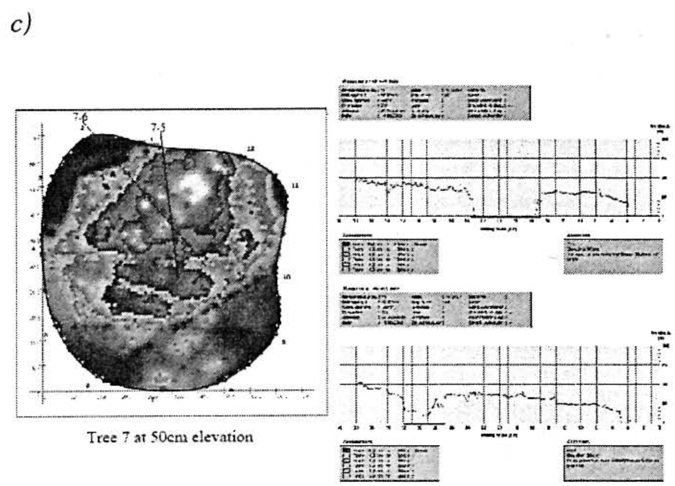


Figure 1.—*Decay detection observations:*

a) tree no. 7 at 10 cm elevation
h) tree no. 7 at 10 cm elevation
c) tree no. 7 at 50 cm elevation
d) tree no. 7 at 137 cm elevation
e) tree no. 7 at 137 cm elevation.

on tree no. 7 was more precise in detecting location and quantity of decay following the acoustic mapping of probable defects by the multi-path tomography than with just the guidance of single-path tests. In conclusion, the protocol using single-path sonic wave testing and visual tree assessment to screen trees for further study, followed by multi-path sonic tomography to guide resistance micro-drilling tests is a reasonable and effective method of detecting decay in red pine trees.

Recommendations

1. Prune deadwood on all trees in and adjacent to the ropes course.
2. Have a qualified forester or arborist visually examine all trees in and adjacent to the ropes course annually and after every major storm event with wind loading levels that could cause structural stability change. Provide that expert with baseline tree decay information on trees no. 1 and 8 to allow careful monitoring of structural changes and decay progression over time.
3. Remove tree no. 7 from the ropes course. ,Multiple-level cross-sectional testing and visible root collar cavity with carpenter ant colonization provide clear evidence of significant, well-established heartwood decay. Even though the sampling test did not confirm a critical risk threshold

Table 2.—*Estimated percent decay and trunk shell wall in sites tested by PiCUS sonic tomograph.*

Tree and elevation level	Cross-section diameter	Percent decay within cross section	Least thick shell wall	Cavity/decay opening	Average wall thickness (cm) greater than 0.33 radius
	(cm)	(%)	(cm)	(as % of trunk **circumference)**	
Tree 1 @ 50 cm	61	6.5	n/a	0	n/a
Tree 1 @ 90 cm	58.7	46.4	0	10	9 (15.5%)
Tree 7 @ 10 cm	76.7	32.3	0	9	17.2 (22.4%)
Tree 7 @ 50 cm	67.8	52.7	0	10	10 (14.7%)
Tree 7 @ 137 cm	57.6	26.4	10.5	0	14 (24.3%)
Tree 8 @ 35 cm	57.8	25	0	8	n/a

of 40 percent cross-sectional trunk decay or a remaining shell wall of less than 15 percent trunk diameter, there is still sufficient evidence to place this tree in the moderate to high risk category, This recommendation is based on the assumption that there is an extraordinary level of risk aversion on a ropes course site with children present, that there are reasonable alternatives to supporting the ropes course cables and platforms, and that is simply better to err on the side of caution in borderline structural stability cases as presented by tree no. 7.

Discussion

Tree safety assessment methods and standards have progressed significantly over the past two decades. The historical record of that advancement in published literature is presented by Joseph G. O'Brien, USDA Forest Service Plant Pathologist in his introduction to the USDA Forest Service publication *Urban Tree Risk Management* (Pokorny 2003). Even though the tools and science based standard formulas have improved with time the problem, as stated by Dr. O'Brien, remains the same, 'While any large tree poses a risk of failure in high winds. in situations where people and trees must live together in close proximity. it is important to identify when a tree has become an unacceptable risk." Experts called upon to render opinions on tree safety are faced with not only the daunting task of discovering and quantifying structural defects but also translating those observations into the probability of failure and determining levels of "unacceptable risk."

The Minnesota Department of Natural Resources publication *How To Detect. Assess and Correct Hazard Trees In Recreational Areas* (Albers and Hayes 1993) describes the challenge:

> "Recreation site managers are in the unenviable position of trying to preserve a recreation site's natural setting while trying to provide reasonable public safety by identifying and then correcting hazard trees. Some tree failures can be predicted on the basis of identifiable defects: some tree failures cannot be predicted... Even the most experienced and knowledgeable arborists admit that the processes that contribute to tree failure are not clearly understood."

Matheny and Clark (1994) echo those conclusions,

> "Identifying and managing the risks associated with trees is a subjective process. Since the nature of tree failure remains largely unknown, our ability to predict which trees will fail and in what fashion is limited. As currently practiced, tree evaluation involves examining a tree for structural defect, associating those defects with a known pattern of failure and rating the degree of risk" (pg. 2).

Even though the biomechanics of tree failure are better understood today than 10 years ago (Mattheck and Breloer 2003. Smiley and Coder 2001), the formulas for assessing wood strength loss are more standardized (Kane and Ryan 2003. 2004) and the tools for nondestructively assessing defects more accurate and powerful (Bucur 2003) the fact remains that deciding what level of defect represents an "unacceptable risk" continues to be a subjective judgment. This is particularly true for trees with significant but not severe defects and on sites that present high levels of risk aversion. Ellison (2005) has developed a method of quantified tree risk assessment that emphasizes the consequences of failure to better describe unacceptable levels of risk during people's interaction with trees. For the present, however. some level of variance of opinion between tree experts in rating tree risk is expected.

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