TCIA Biomechanics, Science and Support Standards

Trees support themselves in mysterious ways. Our job is to keep trees together, so it pays for us to study and solve some of these mysteries, to learn more about how and when to supplement our trees' natural support systems. Imagine a gang of leading scientists and arborists teaming up to tear apart trees with new and unusual gear, then sharing their discoveries--wouldn't that be something to see! All that and more took place August 23-27 at Tree Biomechanics Research Week and Symposium, hosted and supported by the Davey Research Institute and Farm in Kent, Ohio. Organized by ISA, this event solved some mysteries for those lucky enough to attend. It also posed questions about familiar principles and practices, prompting a fresh look at some of the standards on supplemental support systems.

ANSI A300 (Part 3)-2006, 33.2.2 "Structural integrity and potential changes in tree dynamics shall be considered prior to installing a supplemental support system." This standard seems parallel to Hippocrates' dictum to doctors: "First, do no harm." Doctors may make more money than arborists, but don't be too jealous--many pay over $100/day for malpractice insurance! Our patients may not be as valuable, but their biomechanics must be considered when support systems are planned. For example, a 100-year old *Ginkgo biloba* had a large lower limb cabled to the central trunk to lessen the stress on the "U"-shaped union, which had no included bark. This limited its movements in relation to a codominant branch, which years later broke off on a calm day. Heavy fruit set after a wet spring was a factor in this failure.

The "tear-out" wound caused by failure of a codominant limb exposes the central core to cracking and pathogens. For wounds this large, treatment options are limited. Image courtesy of Lewis Ginter Botanical Gardens

Australia's Ken James has measured tree movement for years, building a database of numbers and videos that he shared at Biomechanics Week. By comparing steady, static pull with variable, dynamic pull, James demonstrated how the shock that many climbers experience when rigging out the top of a spar can be minimized by retaining lower branches to dampen the movement. It's the difference between "wiggling"—swaying motions, side to side—and the erratic and unsteady "wobbling". Trees build strength under moderate stress over time in response to movement. That strength can be strained by severe storm loading from new wind patterns, or the removal of adjacent trees, or the immobilization of adjacent limbs. Whe the tree is forced to move in new and unexpected ways, risk of failure is increased.

33.5.3 "Anchors shall be installed in alignment with the cable and termination hardware, and not be subjected to side loading." Lasers can guide cable alignment to minimize side loading, but sometimes tree architecture requires a small degree of pull that is not lined up perfectly with the cable. Side loading can cause catastrophic failure. When a live oak, *Quercus virginiana,* in front of a courthouse grew large, the county wanted to make it safer. Despite the sound structure of the limbs and the forks, large cables and braces were installed, at great expense. Most of this support system did no harm, except for one brace rod that was installed in a large limb that reached over the courthouse stairs. The rod went in perpendicular to the lean, subjecting the limb to severe side loading.

17 years later, on a calm Sunday afternoon, the limb broke at that bolt and crashed onto a sidewalk that bustles with lawyers during the week. While risk assessors and politicians grappled with the issue, the tree was surrounded by a chain link fence. Reduction pruning was proposed to shorten the sprawling limbs and lessen the strain on them. This proposal was rejected due to concerns over a loss in photosynthesis, despite 33.4.2: "When necessary to accomplish the objective, pruning should be performed prior to installing a supplemental support system." A year later the tree was cut down, leaving the lower trunk. The county is now seeking proposals to fashion that tall stump into a work of art.

Utility arborist John Goodfellow, the original proponent of Biomechanics Week, has helped the utility vegetation management industry evolve from tree trimming into line clearance pruning. After directly observing branches bent by snow, he confirmed what other researchers determined--"Observable 'defects' are poor indicators of failure, because they are signs of strengthening, compensatory growth that is optimizing the structure toward a return toward uniform elasticity." Goodfellow's experiments have shown that a 15% crown reduction can increase stability 50%. "Crown reduction is too beneficial a technique not to study and test" he and other researchers concluded. The challenge is: how to specify and communicate dose? Length is one way, mass another. Surface area, as in what would collect snow, is relevant. Eg suggests the area relative to the size of the cut—how to express? Util says fewer cuts, but that approach is not compatible with the findings of this research. More cuts are needed, to avoid the immediate destabilization of adjacent parts, and spread out the tree's response.

Andreas Detter of Germany examined the issues involved with applying the information we get from our testing into safety factors. Devices do not give you the goal without evaluation! Evaluation uses analysis, guidelines, judgments and limits—which can be many, regarding both strength and loading. Strength loss thresholds using formulas are not sufficient alone—short trees can be very hollow, and still reasonably safe. Balance between strength and load determine safety factor. Regarding support, Detter has observed a "karate chop" after static steel cabling immobilized the base of a branch, so the end snapped a short distance away from the fastener. Karate chops are avoided by following 33.6.3.2: "Anchors should be installed at or near a point 2/3 of the length/height of the limb or leader to be supported."

We are responsible for the changes to tree movement resulting from our pruning or support practices. Failure due to immobilization has led to European standards calling for dynamic systems that avoid drilling, but dynamic cabling does not always do the job. An historic oak at the heart of a college campus had two large lower limbs that were cracked to the base. The first arborist followed 33.6.3.2 by installing a dynamic cable at a point near 2/3 of the length of the limbs. Unfortunately, he missed 33.5.19: "All hardware within a system shall meet or exceed the minimum strength required to achieve the objective." The limb twisted too much and broke off, exposing the hollow trunk. After removing the broken limb, a second arborist lopped off a 16" branch near the base of the other cracking limb, but did no reduction pruning. The intention was to make it safer, but the remaining limb is newly exposed to wind, and now has another large wound that will decay. That limb was secured with steel cable, but the SULE—safe useful life expectancy—of this historic tree has been cut short.

How long can hollow trees can be safely retained? It depends on the tree's response. Engineer/arborist Lothar Gocke of Germany demonstrated the use of two devices at Biomechanics Week that deliver images of the inner tree. First he sent sound waves into the stem with a tomograph, which rendered an image that roughly showed the location of a cavity. Next, he sent electrical impulses into the the tree at the same level, which showed a better image of cracks in the trunk. The tomograph can "read" everything inside of a crack as hollow, so careful interpretation is needed. Accurate information is critical in determining risk, and whether or where to install a brace rod. Viewed together, the images reveal a more complete picture of the soundness of the stem. By comparing images taken over time, the silent battle between tree and pathogen indicates potential treatments. If a stem is over 2/3 hollow and increasing, for example, it could be propped on a beam or guyed back to a structure or the ground.

A southern red oak, *Quercus rubra,* has dominated the front yard of a landscape designer for years. Concerned about the tree's lean over power lines and a hole at its base, and arborist was called in to inspect it. A crack extending down from a tight fork has black crusty growth, indicating decay from hypoxylon or *Inonotus sp.* fungi. Of the basal circumference, 80" is dead, ¼ of the total. Probing into the hole with a handsaw did not reach the back of the hole. By inserting a pole, the hollow was measured at 37" of the 53" basal diameter. This degree of hollowness limits the options for installing a guy wire to prevent uprooting, because of 33.4.4: "Anchors and braces shall not be installed into decayed areas where sound wood is less than 30 percent of the trunk or branch diameter." Given these conditions, the owner is looking at installing props to support major limbs and prevent uprooting.

Drilling a hole "no greater than 1/8" (3mm) larger in diameter than the hardware being installed", per 33.5.6, can avoid excessive wounding in decayed areas, if that hardware is the cable itself. "When installing through-hardware", 33.5.10 calls for washers to be used, and 33.5.20 states that "Installations shall follow manufacturers' recommendations". However, the makers of two fasteners on the market that anchor cables installed through limbs, wirestops and wedge grips, do not require washers because these fasteners are wide enough for most applications. It may be best to use washers anyway, until that standard is changed. ANSI standards are reviewed on a 5-year cycle, so they can incorporate new technology and research.

Translating research into technology is a challenge. Concepts like "mechanoperception" and "thigmomorphogenesis" dominated Biomechanics Week. Scientists there agreed that our visual tree assessments have to get better at translating the body language of trees. Restoring objectivity by documenting the positive aspects of tree structure, such as woundwood and other compensatory growth, may be a good place to start. Calling anything out of the ordinary a "defect" can lead to unnecessary removals, or to support systems that do more harm than good. "We looked at one tree with an obvious 'defect', and figured it would break straight away under tension from the four-ton winch" one researcher remarked. "Another tree had no visible 'defects', so we figured the trunk would hold strong, and that tree would uproot instead. But the exact opposite happened! We know next to nothing about tree biomechanics."

More is not always better. This limb was 5" wide when the ½" bolt was installed, though a ¼" bolt would have complied with ANSI. All the original wood rotted, and was being digested by adventitious roots when the limb failed at basal decay. Its codominant was cabled but it was not, changing dynamics and loading. Note that more wood was added on the tension (nut) side, which got more stress after the cable was installed.

Given the uncertainty surrounding supplemental support, arborists need to inspect trees more closely before making any conclusions or suggesting management options. There is much we can learn from the tree's own natural support system, before we impose any treatments. "Form determines dynamic response, so it's time to tune into tree architecture." Ken James told the group. "Much of the scientific data available is based on forest trees, but much of it is not applicable to exposed urban trees. The answer is predetermined by the tree." As much as James knows about tree biomechanics, he does not make recommendations to his clients when consulting about trees. "I just report information to the client" he said. "I let them figure out what to do with it."

We need to plan supplemental support systems with the tree's potential for positive growth responses in mind, and integrate that potential into all of our work. Easier said than done, but once we see trees as organisms linked to human well-being, that shift will be a natural one. We know by looking at trees that have had support systems installed which materials and methods have worked, and which have not. We're all still learning how we can increase the safety of compromised trees by cabling, bracing, guying and propping. The best place to start is by reading and applying ANSI A300 (Part 3) standards.

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References

American National Standards Institute A300 (Part 3)-2006 Supplemental Support Systems