Biomechanics and Support

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, and to figure out how and when to supplement our trees’ natural support systems. Imagine a mob of 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. Organized by ISA and hosted at the Davey Research Institute and Farm in Kent, Ohio, this event solved some mysteries for those lucky enough to attend. At the same time, it posed some questions about some familiar principles and practices.

I drove directly to the site to see if I could pick up some tips on assessing trees’ natural support systems. After parking my rig I was met by one of the most notorious scientists, who offered me a ride to the tree demolition site. I gratefully accepted, stowed my gear, and hopped in.

“These pull tests are amazing”, he exclaimed as we bounced down the road, his bright blue hard hat jostling about on his head. “We looked at one tree with an obvious defect, and figured it would break straight away under tension from the four-tonne winch. Another tree had no visible defects, so we figured the trunk would hold strong, so that one would uproot instead. But the exact opposite happened! We know next to nothing about tree biomechanics.”

“Trees have many mysteries”, I agreed. “Perhaps we’ll get a better handle on them as we see what these guys are up to.” As we approached the group, we heard words like “mechanoperception” and “thigmomorphogenesis” being bandied about. This was getting interesting.

First up was Philip van Wassenaer, an arborist from Ontario, Canada. When an earlier conference on tree biomechanics was held in 1992, he borrowed money to attend. Excited by new methods of measuring tree stability, Philip traveled to Europe to apprentice under a pioneering expert on Tree Statics, Erk Brudi. An expert climber temporarily grounded by sciatica, he has set aside his carabiners, picked up his computer, and carried on. Less physical strain, but a new kind of mental strain accompanies his present work. Reading information sent from sensors on the stem to the laptop balanced on his forearm, Van Wassenaer supervised the destruction of a 6” dbh plane tree, *Platanus sp.* Over 2 metric tons of pulling force were required to break the roots, while the stem held firm.

Next came engineer/arborist Lothar Gocke of Germany, who demonstrated the use of two devices that deliver images of the inner tree, which is hidden from our eyes. 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, which the tomograph does not always show accurately. This new information could be 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.

John Goodfellow of Washington, US, followed with a look from the utility perspective at branches that overhang wires. The damage to tree stability from “ground-to-sky” pruning when contractors take previously reduced limbs back to the trunk has cost utilities , Goodfellow noted along with many others that “Crown reduction is too beneficial a technique not to study.” His work has identified a CFZ—Critical Fracture Zone—where branches typically fail, a short distance out from the origin. Goodfellow found that observable “defects” are poor indicators of failure. Direct observations of branches bent by snow after a storm were extremely valuable. Experiments are being designed with reduction cuts being made at different points on the branch, testing each for strength. In one study, a 15% crown reduction increased stability by 50%. Goodfellow, whose foresight spearheaded the gathering, observed that we cannot control trees, but we can manage them. Reliable electric service remains the goal, as utility vegetation management continues to evolve from tree trimming into line clearance pruning. This work in the US is on the same path as the more comprehensive examinations of tree biomechanics that ETS carries out in Australia.

Dr. Anand Persad represented the Davey Research Institute, which both furnished the trees that were demolished and hosted the symposium. Persad looked at strength lost in ash (*Fraxinus sp.*) trees after being chewed up by the Emerald Ash Borer, in relation to the safety of the crew taking them down as well as the surrounding people and property.

Craig Miller and Tim Newsom of British Columbia, Canada teamed up on science and soil. Basic engineering terms like loading and bending moments and moment of inertia were defined, to give us an idea of the principles involved. After blasting away the soil around a spruce (*Picea sp.*) tree, we could see that roots grew away from competition and into the open. This fact speaks to arborists defining critical root zones in construction projects—the “edge” trees in a grove will sustain more damage from root disturbance in the open areas than our formulas would indicate, because that’s where most of the roots are. Their team sliced into the roots and installed sensors at set locations, then recorded data on how the roots flexed when the trees moved.

“We’ve been three days gathering data, but we’ll be ten years analyzing it. We’ll get back to you then with the results.” We were told. The difficulty of doing research on living organisms exposed to the vagaries of nature also limited other research related to calculating wind load and tree movement. Data for some studies could not be gathered when the wind did not blow. In others,,,The best place to start is the databank of literature at the ISA,,,,

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. For example, a tomogam shows degree of hollowness, but not degree of safety. 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. Detter showed a newly exposed and leaning tree at a school. His wind load analysis used surface area, load center, damping factor, and anticipated wind load. Reduction was recommended, to get the tree into the green zone of safety. Another tree on the site had other aggravating factors that made safety too hard to achieve, and had to be removed. Re 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.

Greg Dahle of New Jersey, US studied tree form as it develops, noting that tree function shifts from sun-collection to structure building. As Louis Sullivan, mentor to legendary architect Frank Lloyd Wright, said in 1896: form follows function, which all changes over time. Wood is a structure, varying with growth. At approximately 10’, radial growth increases as branches spread out to collect more light. The length/slenderness ratio used by foresters translates into branches and can guide our decisions to reduce or support individual branches. What is good branch structure? We know we usually need to reduce or remove codominant and rubbing branches—that’s routine. But when restoring topped or otherwise damaged trees, how do we guide the growth of the crown? “We are flying by the seat of our pants”, Dahl said, though we do have principles and experience to follow. But getting back to the biological basics gives us a fresh perspective, and guides us further.

Ed Gilman of Florida, US has done several studies comparing the effects of different pruning treatments on tree stability, proving that reduction is very effective, thinning is quite effective, and crown raising—removing lower branches—can cause trees to fail. That research was done with 900-horsepower wind machines, generating 190 km/hour hurricane-force winds, which makes for some very entertaining video. The recent work done with pulling tests was a real eye-opener for him: “What looked like defects to us, where we predicted breakage, stood firm as the tree failed elsewhere. The trees that looked free of defects broke at places with weaknesses we could not see. We know next to nothing about tree biomechanics!” Gilman’s work with shaving off the edges of potbound root systems was illuminating—one video of an unshaved root system showed one root moving like a spring, providing much of the stability under tension.

Other researchers focused exclusively on the bottom half of the tree. Blasting away the rich black soil common to the region using the largest Air Knife exposes the root system underground, Jason Grabosky and his team set to work mapping out root systems. Just as branches do, roots add reinforcing tissue where the stress is greatest. “Let’s look at the BIO in biomechanics”, Grabosky said. “All of these factors are strands in a spiderweb. How do roots grow in secondary thickening? Roots form a mat in the interior. Long roots move with wind and optimize their form. This work is difficult and expensive, and better done in collaboration.” Jason’s done a lot of research with branch pruning, and his work on small root development helped advance the development of structural soil. Having big tools to study big roots was something newith ledhe’s unaccustomed to working with roots. He learned one lesson the hard way—his wedding ring is buried somewhere on the site.

Australia’s Ken James has measured tree movement for years, building a database of numbers and videos. 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 wiggling in set patterns. That strength can be strained by severe storm loading from new wind patterns, or increased exposure due to the removal of lower and interior branches or the clearing of adjacent trees. When movement is no longer dampened, the tree,,, The same principle extends to routine pruning—retaining lower and interior branches builds stability. This is why lion-tailing a tree by stripping out the inner branches, or raising Cain by stripping lower limbs, is so harmful. “Form determines dynamic response, so it’s time to tune into tree architecture. It’s also time to set aside plantation (forestry) tree data—much of it is not applicable to exposed urban trees. The answer”, James wisely concluded, “is predetermined by the tree. “ As much as James knows about tree biomechanics, you will not catch him making a lot of recommendations when he does his consulting. “I just report information to the client” he said. “I let them figure out what to do with it.”

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So how can we apply the huge range of pruning possibiliities to production arboriculture? Some general principles came out of this mob of scientists’ destruction of trees:

1. Reduction cuts properly made are good for structure
2. Thinning cuts, properly made and in moderation, can also improve structure
3. Removal of lower branches has several negative effects on tree structure
4. Removal of large lower branches can be catastrophic—how to avoid it!
5. Abnormalities in form are often misinterpreted as “defects”, sending false signals to the trained and untrained eye alike.
6. Root damage is deadly to tree structure
7. Offering opinions is risky, without full confidence in one’s knowledge

Philip van Wassenaer perhaps summed it up the best: “We need to shift our thinking and our training to pruning with the tree’s potential in mind, and integrate that into corporate culture.” Easier said than done, but once we see trees as organisms linked to human well-being, that shift will be a natural one.

Many of these researchers will converge on Parramatta, Sydney, Australia, at the ISA conference in July of 2011, to report on these studies, and much more. They may provide you with tips for carrying on with the care of trees, and the confidence and gear needed to do it well. See you there!