TREE Fund Webinar
Arboricultural Biomechanics, 645-818-934, Aug 23, 2018
Dr. Brian Kane, University of Massachusetts, Amherst

Dr. Kane's answers to the questions that came in during this webinar are below:

<u>General Comment</u>: my responses to questions below are based on applying simple Physics to trees and the experiments that I've done (or that I've read about). But without doing many more experiments, it's hard to know for sure whether applying simple engineering approaches to complex structures like trees is reasonably accurate. There are many variables that can affect the outcome of an experiment on trees, so just because one experiment showed that cabling increased sway frequency on leafless red oaks growing near the UMass - Amherst campus, that doesn't guarantee that cabling will always increase frequency on other species growing in other places. Many additional studies would be needed to confirm that cabling leafless trees increased sway frequency.

Q. We may know from experience which tree species are stronger than others. But is there a university document that gives actual data of strength by tree species?
A. In the USA, the *Wood Handbook* provides strength properties for many species, but it's important to remember that those values are for test specimens, not actual trees. Studies have shown that the specimen values overestimate tree strength.

Q. If gust & sway frequency are similar, stress is multiplied; when are they different?
How are tree sways quantified between back-and-forth swaying?
A. Gust frequency is a measurement of the frequency of the wind—that is, how often do gusts of wind "push" on a tree? Sway frequency is an intrinsic mechanical property of the tree, just like wood strength or diameter at breast height. Sways are measured in cycles per second or Hertz (Hz), and one complete sway is from the starting point (equilibrium) through bending all the way in one direction, then swaying back through equilibrium to the opposite side, and then back to equilibrium.

Q. Please repeat the comment about how / why gust frequency and sway frequency is worse than dynamic or static loading.
A. When gust frequency and sway frequency are the same (or similar), stress is greater, even if the force of the wind doesn't increase. This is called dynamic amplification.

Q. What are your thoughts on the concept that reducing a tree might reduce the dampening effect and thus reduce stability on the tree as a whole or individual limbs?
A. At moderate pruning severity, reduction pruning did not significantly decrease the damping ratio, so it's probably less of a concern. But as pruning severity increases, damping ratio decreases, and reduction pruning had a greater effect than other pruning types.

Q. Are there results or a paper on the study done with the trees in the back of the truck?
A. We published this paper in *Arboriculture & Urban Forestry*; you can download it here: <http://auf.isa-arbor.com/request.asp?JournalID=1&ArticleID=3051&volume=34&issue=4&Type=1>

Q. Pruning severity reducing wind force refers to thinning only, as opposed to reduction?
A. Any type of pruning will decrease wind force (or "drag") roughly in proportion to how much you prune. Decreasing drag will also decrease the bending moment because bending moment is force (or drag) multiplied by the lever. Reduction pruning also decreases the lever, so it's more

effective than other pruning types at decreasing bending moment (assuming that the same amount is pruned). Raising increases the lever, so it's less effective at decreasing bending moment. Also, relative to the amount pruned, reduction pruning removes proportionally more leaves, which experience greater drag than leafless branches. So reduction pruning is generally more effective at reducing drag-induced bending moment. (But this only applies in the short-term; I'm not aware of any studies that have measured the effect of pruning in the long-term.)

Q. I'd think that the longer lever resulting from raising the canopy would change the damping ratio, even at 25%.
A. Intuitively, this makes sense, but the experimental evidence (so far) hasn't shown the effect.

Q. Presumably the moderate pruning in the example is distributed uniformly throughout the crown?
A. Yes; when we thinned trees in experiments, we followed the guidelines in ISA's BMP on pruning, attempting to mimic what an arborist would do in real life.

Q. As presented, the more reduction in height and/or canopy size, the lower the stress. In our industry standards, we limit amount removed in 1 pruning cycle to 25%, to not stress health greatly, and to reduce level of reactive sprouting (and other reasons). These are opposing points—prune more to reduce likelihood of failure versus prune only to a limit. How do they reconcile in research analysis done so far?
A. Simply pruning more to reduce stress and the likelihood of failure is not a good idea for the reasons you mentioned. It's definitely a balancing act between reducing the likelihood of failure and maintaining tree health. It would be very helpful to have some long-term studies to investigate how pruning severity affects tree health. Foresters have studied pruning for a long time, but the pruning they do and the growing conditions for the trees can be quite different than for amenity trees.

Q. Are you discussing the effects of pruning on individual limbs or on the entire tree?
A. We've only measured the effect of pruning on whole trees—we measured forces and sway motion in the trunk, rather than on individual branches.

Q. Leaves improve the damping effect of trees, so would not reducing / thinning the crown and removing the leaf area not reduce the damping effect?
A. Short answer: Yes. But the experimental evidence (so far) has shown that there is little effect at moderate pruning severity—substantially more pruning has to be done to show an effect.

Q. If cabling doesn't substantially alter the frequency of sway, does that mean that there's less impact than we used to think on stem taper in the new growth post-cabling?
A. In one experiment, we measured stem diameter growth before and after installing different types of cables and did not observe changes in diameter growth (aside from a spike in growth where we drilled a hole to install an eyebolt, which was presumably callus wood formation). <https://www.sciencedirect.com/science/article/pii/S1618866714000363>

Q. Where was the position of devices when the influence of cabling to frequency was measured?
A. We've installed accelerometers at different points along the main stem and on co-dominant stems (for different experiments). The location did not affect the sway properties, presumably because we measured the natural sway frequency of the trunk. <https://link.springer.com/article/10.1007%2Fs00468-018-1690-3>

Q. Would it be safe to assume that the reduction in dampening by a leafless tree is self-corrected by the corresponding increase in sway frequency?   Do those dots connect as a rule of thumb?

A. Very difficult to answer, unfortunately. It seems like an intuitive evolutionary adaptation, but one computer simulation we did showed contradictory effects of leaves on the likelihood of failure <https://www.sciencedirect.com/science/article/pii/S0266892014000277>.

Q. Have there been any studies done on the effects of bracing and cabling on defective branch unions - such as a reduction in reaction wood to strengthen unions?
A. <https://www.researchgate.net/profile/E_Smiley/publication/265656591_Brace_rods_for_codominant_stems_Installation_location_and_breaking_strength/links/5693fc0e08ae820ff0729d9d/Brace-rods-for-codominant-stems-Installation-location-and-breaking-strength.pdf>, <https://www.researchgate.net/profile/Duncan_Slater/publication/308148077_An_assessment_of_the_remodeling_of_bifurcations_in_Hazel_Corylus_avellana_L_in_Response_to_Bracing_Drilling_and_Splitting/links/57e5249308ae9022415a4033/An-assessment-of-the-remodeling-of-bifurcations-in-Hazel-Corylus-avellana-L-in-Response-to-Bracing-Drilling-and-Splitting.pdf>

Q. From your graphs, it appears that the effects of reduction vs. thinning cuts provide very similar effects on the overall likelihood of failure. Is this a correct interpretation of what you presented?
A. Assuming the same amount is pruned from the crown, reduction pruning more effectively decreases bending moment than thinning <http://auf.isa-arbor.com/request.asp?JournalID=1&ArticleID=3051&volume=34&issue=4&Type=1>.

Q. How well do your results apply equally to stands vs.individual trees?
A. Some of our work has been conducted in relatively open forest stands, and some has been on individual, open-grown trees. Wind is very different in open areas and forest stands, so if you're working in a forested setting, it would be best to read the Forestry literature on wind and trees. This book is a bit old, but a good starting point: <https://www.cambridge.org/core/books/wind-and-trees/DAF79DE9A7F27C6AC3C6FFC18EEB2B3B>

Q. Is there an optimum height for each tree species in particular, if that height is not its natural height?
A. I think an important tree measurement is slenderness, which is the ratio of tree height to diameter at breast height. Forestry studies have shown that slenderness can influence the likelihood of failure. But on open-grown trees the measurement might be less useful since the trunk often bifurcates.

Q. Wood properties are much less important for the calculation of the load carrying capacity than the size of the cross-section.
A. That's a good point. Moment capacity increases as the cube of diameter, so a doubling of diameter increases capacity by a factor of eight. In comparison, species with "strong" wood are, at most, four to five times stronger than species with "weak" wood. So a weak-wooded tree with a 20" diameter trunk is still stronger than a strong-wooded tree with a 10" diameter trunk.

Q. Does the *Wood Handbook* speak to green wood values?
A. Yes, it has values for both green wood (wood freshly sampled from a living tree) and kiln-dried wood (usually at a specified moisture content, like 12%). Below fiber saturation point (roughly 35% moisture content), moisture content can influence wood strength and stiffness. <https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr190.pdf>

Q. It would be great to have a presentation like this with practical applications and pictures. Given that wind direction, shape and location of decay and species are so critical, it's challenging to learn across all of those dimensions, so I can understand why it would be hard.

A. Agreed. It might be helpful to use the concepts we discussed in the webinar to supplement or complement your experience working with species and growing conditions where you work. Good experience along with some basic understanding of mechanics, can be very insightful.

Q. Are there one or two particular characteristics of wood that determine its strength? I'm thinking about a uniform bar of solid wood.
A. In general, the best predictor of wood strength and stiffness is the wood's density (sometimes expressed as "specific gravity").

Q. Where can we learn more about sway and gust frequency?
A. <https://www.cambridge.org/core/books/wind-and-trees/DAF79DE9A7F27C6AC3C6FFC18EEB2B3B>

Q. Frank Rinn has said not to cable at all, particularly codominant stems w/acute-angle attachments, but limit support to thru-bolts at the attachment, i.e., reduce risk by reduction pruning only. Comments?
A. I'm just starting an experiment to examine the different effects of cabling vs. bracing on tree growth, attachment strength, and sway frequency and damping ratio. Hopefully, in 5 years, I'll have some insights.

Q. A question on pruning: Lions tailing did not reduce frequency and did not increase the bending moment. Is this correct?
A. We didn't measure the effect of lion's-tailing on frequency, and, in general, it decreased drag and bending moment, but there are good mechanical and physiological reasons not to do it: <https://www.researchgate.net/profile/E_Smiley/publication/237866489_Drag_coefficients_and_crown_area_estimation_of_red_maple/links/5727496d08aef9c00b8b425c.pdf>

Q. Are you aware of the "roughness factor" associated with different terrains and land uses and how that affects the statics and dynamic forces on a tree or a group of trees?
A. Wind is very complicated (which is why I study trees!), and roughness factor is an important influence on the wind. There's a chapter in this book on Forest Meteorology that describes how terrain influences the wind https://www.cambridge.org/core/books/wind-and-trees/DAF79DE9A7F27C6AC3C6FFC18EEB2B3B>.

Q. In the cabling of trees, what is the better choice in the long-term: dynamic or static systems, wire vs. Cobra type for the biomechanics for trees?
A. We've only compared stem growth in response to both types of cables <https://www.sciencedirect.com/science/article/pii/S1618866714000363>. My gut feeling, based in part on the results of that experiment, is that properly installed steel cables do not limit the sway motion of stems enough to alter stem growth. It would be helpful to have more long-term experiments looking at whether different cabling systems alter the sway motion and likelihood of failure.

Q. Thanks for a great presentation. At the beginning of the meeting Dr. Kane mentioned a UMASS arboriculture group. I am an alumni - Class of 1990, can I get more info?
A. <https://m.facebook.com/groups/1404563269812721?ref=bookmarks>