

Kim Coder: The Meaning of Tree Biomechanics to Tree Health Care Providers

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Music: [00:00:00] In every country, you know we can work together and learn what we need to meet the challenge. Traditional skills and modern techniques, whatever language you speak, you have a world to offer every day, climb with the ISA.

Jamie Vidich: Hello and welcome to the Conference rewind videos. I'm Jamie Vidich, director of Educational Products and Services at the International Society of Arboriculture.

Today, we are pleased to bring you a presentation by Dr. Kim Coder, The Meaning of Tree Biomechanics to Tree Health Care Providers. This presentation was originally given at the 2021 ISA Virtual Conference. So the views are those of the presenter. If you are interested in tree biomechanics, I expect you will like this presentation.

So sit back and enjoy.

Kim Coder: Well, hello. Let's talk about the meaning of tree biomechanics. We have a lot of research that has gone on in tree biomechanics and I have reviewed about 50 papers for you. I've actually looked at more than that, but these are the 50 I thought were, were important. And the tree biomechanics researcher is composed of a lot of different places in a lot of different areas, and they're keeping some secrets from us that you need to know. So that is why I'm going in to help you, look at these research papers.

So in tree biomechanics research on wind a lot of them are hidden in journals like wood science, botany and plant science, engineering journals, structural [00:02:00] mechanics, and of course, agriculture and forestry are the ones that we see the most often, but there's a lot of information out there not in just the agriculture and forestry journals. And many of these papers, you get lost in the math lost in the experimental design. And so you get lost in translation when we're trying to apply it to the field.

Now, in this research, about three to four times the papers have been written, been posted in the last 20 years compared to the previous 20 years. We are continuing to accelerate new refereed journal papers, new research reviews, which are fantastic, some new research books, and they're not blogs or someone's opinion on a podcast. It's not client hearsay from the field. It's not the first entry on a web search. These are referee journal papers that have gone through the whole review process and they're, they contain research secrets and gems for the field for our trees that will give us better tree quality. So we're trying to figure out what the facts are and their truth.

So if we're gonna do tree biomechanics, we better figure out what trees are. Remember they're tall, woody, perennial plants, tall, keyword, porous, and flexible sail up in the wind, keyword, flexible, it's on a tapered mast, it has a dead passive core covered by a reactive skin and the skin reacts to wind load changes, and it sits upon and [00:04:00] is woven into a near surface soil matrix. And trees react to large and long wind gravity displacements. They don't affect or are not affected by a little bit of breeze here and there. It takes long and large wind and gravity displacements for the tree to start to react.

Now, with wind loads, the load components we worry about are the wind velocity and associated wind pressure. And remember, it's the wind pressure that pushes on the tree. That's the important thing, and it's the square of velocity. So as velocity increases, wind pressure goes up a lot. Gust and calms, the tree is loaded and released tree crown reconfiguration, it streamlines, or falls back against the wind, sway and damping, especially under wind loads, wind velocities under 20 miles an hour, and whether the foliage is on or off. These are wind load components. They're highly variable and that is the environment the tree lives in.

So what makes a stable and resilient tree? Well, wind challenged trees, you get wind bending and flexing, swaying and damping over long periods of time generate more stem rigidity, diameter growth, less height, reduced branch mass, and more and larger roots. Wind and gravity loads change the structure of trees, [00:06:00] diameter and height changes. If we had two things to really pay attention to, diameter increases, which provides stem and branch stability and sway damping, and height and branch length decreases, decrease bending loads and drag coefficients. We get less failure risks when we do diameter and height.

So what are the tree components that lead to success? What are the structural success points of trees? We reduce the risk from applied wind loads by a smaller crown mass, greater live crown ratio, less total height and less functional height, and that's just the center of load in the crown, increased stem taper, increased stem diameter, larger stem base and root base diameter, an increased root plate diameter, and larger root to shoot ratios. These are the things that give us success that minimize risk of failure in trees. So if we're gonna sum up the biomechanics here for success and sustainability, we increase diameter, we decrease height and mass. We want a tree that is stem base weighted, not top weighted. Stem base is survivable. Top weighted is prone to damage.

We also need to remember about tree structure itself. The tree is continuing to continually modifying its wind resistance with two [00:08:00] contrasting and opposite mechanical changes. It continues to put flexibility in the top two thirds, the outer two thirds of it, around the periphery, it becomes more flexible. This is the elastic resilient in the stem top. It also is generating basal stiffness in the bottom two thirds. You get more rigidity through diameter growth near the stem base. And in the middle, we have a transition zone where the stiffness is component from the base is slowly shifted upward over time. As the tree ages, the transition moves up, the stiffness component moves up. This is what supports long term survival in trees.

Now, we also have some issues with tree reconfiguration. This is where trees streamline, reorient themselves or reconfigure their crowns to reduce wind loads. They fall back against the wind. The frontal area decreases, the drag coefficients decline. You get three levels of reconfiguration based on wind pressure loads. A plastic. Brittle is where we have breakage, and then destruction when we get just too much load on the tree. And we gotta remember that in a land of ice storms, ice coatings greatly change reconfiguration and prevent effective reconfiguration. This example is a plastic reconfiguration index. We have wind speed and [00:10:00] wind pressure and pounds per square foot on the crown, and notice that we reach tree crown reconfiguration at about 55 to 65 miles an hour, about 8 to 10 pounds per square foot on the frontal area of the tree. And if we have ice on the tree, we actually reach tree reconfiguration values much at much less 28 miles per hour.

So here is our crown reconfiguration. Our plastic, our flexing deflation maximizes out at 55 to 65 miles per hour sustained wind. That's a frontal pressure on the tree of 8 to 10 pounds for every square foot of tree tissue. And that's load threshold one is getting through reconfiguration. Brittle or breaking in compression fault reconfiguration maxes out at about 95 to 105 miles per hour, frontal pressure of 24 to 28 pounds per square foot, and this is load threshold too. By the time the tree reaches this level, it is burned through it's genetic safety factors that have been designed in it to keep it up and going. And then

beyond 105 miles an hour sustained wind, we get just massive destruction, tension faults, neutral plane faults, compression failures. And at this level and beyond we get tree loss and major structural failures regardless of what tree attributes are out there.

So if you take a look at elastic reconfiguration, how the tree [00:12:00] streamlines and falls back against the wind that is up to 55 to 65 miles an hour threshold one, and then we burn through the safety, the engineering genetically engineered safety factors in the tree by 95 to 105 miles an hour. Now, why do we care? Well, because if we're looking at pruning and reconfiguration, pruning is streamlining. The things that we do is streamlining the tree. It reduces the frontal area in this case in this example, if we reduce the frontal area by 32%, that is equivalent to trees

streamlining in 40 mile an hour winds. It's a way to keep in the back of your mind that a little bit of pruning can have a great influence on reconfiguration.

All right. Well, enough of the research stuff. What do those papers tell us about what we do? What are the practices for stable and resistant, stable and resilient trees? Well, first pruning, remember we can reduce height through reduction. We can reduce the extent in reach of large branches through reduction or a bridging. A bridging is just shortening. We can reduce crown density by thinning. We can reduce frontal area to generate less sale, and we can reduce crown and branch asymmetry, lopsidedness. All [00:14:00] of these items can all reduce the applied wind loads, all reduce the failure risk, and all of the them are something we can do something about. So when we're talking about a tree height reduction and you couple that with symmetrical crown mass control, we don't want asymmetrical crowns, we don't want lopsided branches and crowns, and minimize crown raising, that gives us tree stability and sustainability.

And we have a a history of over raising or raising too quickly tree crowns, and some of this is quite abusive based on the live crown ratio. So again, we need to minimize crown raising. When we're pruning in the crown, we gotta change crown mass and distribution, sway and damping, decreasing drag all through pruning. And we get lower risk by reducing bridging main branches, but not removing them. Lower and middle third branches in the transition and the stiff zone of the tree have great value for survivability of the tree. Transient branches on young trees provide food and damping, and they're valuable. So we shorten branches, not remove.

Another thing that research is showing us is on the crown raising, if we increase the height of the applied wind load center, if we move it up into the flexible zone of the tree, if we move it higher into the tree, we increase the [00:16:00] functional height. And so that means that raising over cleaning lions tailing all change wind loads and focus that load upward and outward, which has great risk potential for the tree. We abridge, not remove those branches. We need to minimize raising. If you look at raising over here, you notice that as we raise the crown, we are greatly increasing the load it's under. And you say, well, there's less, there's a whole bunch of less sale. How can that be? Because you're placing a lot of mass up high in the flexible part of the tree. What about crown reduction then? If we're not gonna do raising, let's do crown reduction.

So crown reduction will decrease applied wind loads, it'll decrease functional tree height in the wind loads center, and it will decrease branch length, because we are abridging, we're shortening, not removing. And if you look at the load with crown reduction, we get a great savings in the actual wind load through crown reduction. Now, one of the things that can be confusing when you think about it too long is live crown conservation, large live crown ratios, and that is the crown height versus the total tree height. Large live crown ratio maintains tree reactivity. So it can adjust well to applied loads, it can lower the wind load center in the tree, and it modifies sway and damping. Live crown ratios, as they increase, [00:18:00] failure risk decrease.

And you say, well, we got more sale. How can that possibly ? We do have more sale, but we're changing how the tree dynamically moves in wind. Live crown conservation, we try to keep any of the big limbs in the lower half of the tree in the stiffness or transition area of the tree. The mechanical transition zone below the most flexible areas where the big branches need to be because they can absorb and damp applied wind loads. We abridge their length, but maintain the branches. Now, in some cases, some researchers are suggesting that small live crown ratio trees should be removed. You increase live crown ratios, you decrease potential wind damage risks.

Another point of crown control the research is telling us is large dense crowns in the wind transfer large loads to stem and root base. A large crown mass just because of its mass has a higher failure

rate. So we decrease crown mass to reduce failure risk. We shorten, abridge large branches, not remove them. We also can manipulate crown porosity. Now, if we do small crown thinnings, if you're just dinging around out there doing a little bit of thinning, you actually will increase drag and wind loads on your tree. More intense crown thinning, greater than [00:20:00] 40% aerodynamic porosity or greater than 20% optical porosity, more intensive crown thinning actually increase crown porosity and reduce supplied wind load. So a little bit will get you into trouble, but a little bit more of crown thinning will help.

We have a terrible problem with asymmetrical crowns and branches. Lopsided or asymmetrical crowns generate twist or torsion. Tissues under torsion take less force to break or bend. Less applied wind load is needed for stem and branch failure if they're under tension or, I'm sorry, under torsion or twist. Lopsided crowns and lopsided large branches are the primary drivers of failure both in wind and ice storms. So in asymmetrical crowns and branches, the asymmetrical loads along the tree height and branch length mean that you're gonna have uneven applied wind loads and failure risks causing twist, causing torsion. So if we decrease the height, you take large co-dominant branch links back, abridge them, you get rid of forks and weak confluences, and you get rid of lopsided tops that will help it applied wind load resistance. You gotta prune back towards symmetry.

What about leaners? Well, applied wind loads amplify compression loads. Once you get over about a three degree lean, we're starting to have both a [00:22:00] wind interaction and a gravity interaction. Just as a rule of thumb just to think about is if you have a wind speed load of 22 miles an hour, that is equivalent to a lean angle of about 15 degrees in the actual wind load that you're getting. So the point is many researchers are suggesting that leaning trees should be removed, because a leaning tree is an asymmetrical gravity load. What about root structure?

Well, there's a lot of constraints on root structure. This is a side view of a root plate in a ZRT, in a unconfined, soil. But we have all kinds of constraints, hard scape and infrastructure installation and presence, soil compaction, aeration, and drainage issues, impervious layers before, below ground. These constraints shift the roots to a shallower, but a wider ZRT and root plates. That means they're gonna be closer to surface problems, closer to drought issues, flooding issues.

So this is looking down on a root plate, and in root plate mechanical issues, what we can do, and these are all very good, common sense things that the researchers have come up with, keep off the root plate, duh, no compacting events, no trenching, no root and stem based injury, and do not shift the functional balance between shoot and root growth. What we're trying to do is develop a healthy soil, a healthy site. We're trying to be ecologically literate [00:24:00] in having the best tree we can. Now, in tree growth interference, we wanna make sure we cultivate a functional balance between the tree components. Fertilizers modify internal growth allocations, that's why we use them. But excess enrichment of nitrogen and phosphorus generate physiological imbalances, poor structural responses and wind load risks.

What about as the tree ages? Well, tree stability with age as a tree ages, it increases the applied wind load applied to the crown. So we get an extension of height over time, expansion of crown reach and extent over time, increased diameter growth and changing height diameter ratios or taper. So we get greater rigidity in the stem, greater elasticity around the crown periphery. Age and size changes increase the vulnerability risk for taller, older and bigger trees. For example, the environment tries to constrain a resource gathering and control by a tree. The genetic biological potential of the tree continues to try to expand, colonize, and control resource space. If the environment wins, the tree declines and dies. If the tree wins, then it thrives.

Now, the other component that we can worry about in tree aging is we know that these biomechanical features change with time, age, growth, gain in living and dead mass, and [00:26:00] extent in reach this causes transport complexities that increase and can age a tree prematurely, especially with a lot of injury, a lot of compartmentalization. Tree frontal area crown mass, lever arm length, and drag increases with aging. Applied wind loads and vibrations increase with aging. And that means that the stem diameter and the root plate diameter has to increase, but unfortunately, they, they increase at different rates. So this generates a load resistance gap. And that is why when you think about little trees break and big trees uproot, they are investing in different things as they age.

All right. Take a big deep breath, sigh of relief. We haven't had many mathematical formula or anything in biomechanics, but how do we conclude this? Well, first of all, tree healthcare, if you take a look at a number of stability formula, I'm just gonna pick on this one height is the most important feature in tree stability, frontal area, tree crown shape, especially, if they're asymmetrical, drag coefficients and above ground biomass. These five things are stability variables that can be modified by pruning. We can do this.

We also have a problem in remembering it's not just about the tree, it's about its surroundings. If we clear [00:28:00] and remove around trees, we change the applied wind loads. We modify neighbors or neighboring trees and structure, and we get a reallocation of growth to acclimate to new loads. So new load conditions will take time for the trees to react to. You gotta be patient. So what we're gonna do is remove over mature, poor form and damaged trees, initiate proactive pruning programs, and improve rooting space, aeration, drainage, compaction and rooting volume. So we gotta be patient. We gotta lose, lose the bad stuff. We just can't keep harboring the bad stuff. And we have gotta make site and trees better to active management, active care.

We gotta remove initiate and improve.

So research is telling us, research is showing us proactive pruning programs reduce damage. Effective pruning help tree survive windstorms. And active tree care programs minimize failure risk, a tree that is arborist enhanced. An arborist enhanced tree is the best thing to put on a landscape, to keep on a landscape for generations. So understanding and appreciating the meaning, you always gotta get to the meaning. You gotta dig through all the other stuff to get to what [00:30:00] matters in the field to our clients, to our trees, and to our quality of life in this profession. Thank you.

Music: Traditional skills and modern techniques, whatever language you speak, you have it world to offer every day climb with the ISA.