Dr Ken James (fourth from left) explains the tree-measuring data to delegates

State-of-the-art devices include tree movement sensors and accelerometers

BLOWING IN THE WIND

Earlier this year, the Institute hosted four workshops led by Dr Ken James, one of the world's leading researchers in tree biomechanics. Dr Dealga O'Callaghan FICFor, who was instrumental in bringing Ken to the UK, reports

It was a real coup to persuade Dr Ken James, formerly of Australia's University of Melbourne and now working with ENSPEC Environment & Risk, to travel to the UK and lead the workshops on his research into the "Dynamic Structural Analysis of Trees Subject to Wind Loading and the Biomechanical Implications". Four workshop locations were chosen – Croxteth Hall in Liverpool, Derby Arboretum, Barcham Trees in Ely and the Royal Botanic Gardens, Kew – and, as the ICF representative, I attended all four and here describe some of the content covered at what delegates agreed were excellent days.

Ken began with the science of static and dynamic movements in trees, explaining the complex mathematics and engineering principles of dynamic motion, damping and mass damping very simply such that

This data set clearly shows that trees are a lot more stable than we think they are

all delegates obtained an essential understanding of these principles quickly and, indeed, how they apply to trees.

Ken described four basic tree types and their movement in wind: small/young trees up to 10m in height; larger trees between 10m and 50m – distinguishing between trees that are open-grown (urban trees) and those growing in forest plantations; and giant trees such as *Sequoiadendron giganteum* and *Eucalyptus regnans* that can reach heights of over 100m. For these workshops, Ken concentrated on the open-grown or urban trees, explaining that trees in forest plantations behave very differently in wind than open-grown trees.

The data Ken presented is the measured movement of tree root plates using tree movement sensors (TMS) he developed during his PhD. The sensors are made by Argus in Germany and have a battery life of 20 days. They record the movement at the tree base 20 times per second. They also have a GPS device, together with three accelerometers that allow the measurement of movement in the lateral, horizontal and vertical planes. A 20-day monitoring period produces 74.5 million readings that are recorded on a micro-SD (secure digital) card within the sensors.

A number of points emerged early on. Firstly, big trees are not scaled-up versions of small trees. Large, open-grown trees behave completely differently in wind to

Dr Ken James delivering the first workshop at Croxteth Hall, Liverpool

small trees. Secondly, branches play a significant role in "damping" movement in trees; they are, in effect, "mass dampers" and move against each other in wind, the effect of which is to dissipate wind energy and effectively reduce movement in the stem and down to the root plate. Leaves play the key role in branch effectiveness as mass dampers. The dynamic response of trees to wind pressure does not differ between species but, rather, it is dependent upon form, size and branches. Another key element that must be considered is the "wind environment" of the trees. By this, Ken means the normal winds to which trees are exposed annually, not the extreme high winds with long return periods.

There are implications here for the effects of pruning as removal of branches will affect the mass damping. Ken quoted Ed Gilman[1] and James Urban[2], who have both suggested from anecdotal evidence that pruning can increase a tree's exposure to the wind environment.

Using motion sensors, Ken has recorded movement in 250 open-grown trees in high winds over a number of years. Only one tree failed while being monitored, despite Ken asking professional arborists to point out trees they considered likely to fail. Ironically, the tree that failed was not one of those. The monitoring data showed the last ten hours of the tree, pinpointing when major roots snapped. Ken has concluded that when trees fail in their normal wind environment, it is usually a result of being exposed to multiple wind events over time or multiple strong gusts during a storm.

These measurements have provided a data set against which monitored trees can be compared. This data set clearly shows that trees are a lot more stable than we think. ENSPEC can now assess monitoring data from any tree and set it in one of three zones of stability based on the tilt angle of the root plate recorded in wind. In the green zone, a tree is said to be within the limits of stability, in the red zone the tree is outside its limits of stability, while the orange zone indicates that the tree needs to be assessed more closely with a view to management. Based on the data analysis, ENSPEC can generate a legal report as one of its services. All the trees that the arborists said would fail were within the limits of stability and all are still standing!

There was much food for thought and we do need to start looking at trees differently. Well done to the ICF for hosting this event. Hopefully we will see more of Ken's research data in the future.

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References

1. Ed Gilman is Professor, Urban Trees & Landscape Plants, at the University of Florida Environmental Horticulture Department.

2. James Urban is a leading voice in landscape architecture for the arboriculture industry. His consulting firm, Urban Trees and Soils, is based in Annapolis, Maryland, USA.

When are we... RESPONSIBLE?

Ken says we can learn from engineers and their experience

Ken posed a question as to the limits of an arborculturist's liability when undertaking tree risk assessments. This was debated in each workshop and the general view was that we should not accept liability for tree failure in extreme wind events, but should operate to the normal wind environment in which the tree(s) is located. So, in Britain that is up to storm force (55-63mph/48-55 knots) which is the point on the Beaufort scale when trees and parts of trees fail but not the extremes found in the 10 to 20-year return periods storms or, indeed, the exceptional winds with longer return periods such as the 1987 hurricane. We need to learn from engineers who do not design buildings/structures for the extremes; they design to a specified "engineering design load" for the location of the building/structure and test to about a third to a half beyond that as a "proof test". Engineers are not liable when buildings/structures fail in extreme abnormal wind conditions, so why should arborists be liable for trees that fail in those conditions?