‘TV-Oak’ in Stockholm

Evaluation of wind load and tomographic measurements from Nov 2011

**Summary:**

Relative strength loss in the cross section measurements ranged from ~20% up to ~32%.

Assuming 40% strength loss, the stem breakage safety factor of the mature oak is still significantly higher than that of young intact trees, leading to a correspondingly very low likelihood of failure.

In addition, a crown pruning as suggested would still have preserved the habitus but reduced wind load by 40%, bringing the safety factor back to the original level (of the intact tree).

Both approaches show that stem breakage probability provided no reason to cut down the oak.

*All subsequent analysis is based on data and pictures received from Jon Hartill, Gothenburg.*

**Content**

- Wind load analysis (ArWiLo™) 2
- Stress wave tomography (ARBOTOM®) 6
  - Testing of the oak stem on Stockholm tree conference (May 2012) 6
  - Strength loss in 5 tomographic cross sections of the standing tree 10
- Estimation of load carrying capacity of the standing oak stem 13
- Possible wind load reduction pruning 14
‘TV-Oak’ in Stockholm

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Wind load analysis (ArWiLo™)

Worst case scenario wind load analysis: assuming a fully closed crown at maximum dimensions and maximum assumable wind speed (hurricane, 36m/s), coming to approx. 175kNm bending moment at the stem base.
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If the empty areas are taken out of the sail area, this leads to a reduction of the estimated maximum assumable wind load of about 30%.
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If, in addition, topology and density of the crown are taken into account, this leads to a reduction of the estimated maximum assumable wind load of about 55%.
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**Evaluation of wind load and tomographic measurements from Nov 2011**

If, in addition, the terrain exponent is set to urban town center, the estimated maximum assumable wind load drops down by more than 60% as compared to the original worst-case scenario.

The real wind load at the stem can be assumed being much lower as estimated in the worst-case scenario.
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Stress wave tomography (ARBOTOM®)

Testing of the oak stem on Stockholm tree conference (May 2012)

The following pictures show how the stress wave tomogram in this case reflects the internal condition.

This measurement of the oak stem was done at the Stockholm Mature Tree Seminar in May 2012.
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Based on the previous line graph, the ARBOTOM® computer program calculates and draws this representation of the cross section, primarily not revealing wood condition but further more mainly representing the load carrying parts of the cross section.
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This overlay module of tomogram and picture of the cross section shows how close the colors represent the load carrying parts of the cross section. Because no sensors could be placed where the stem laid on the ground (between sensor #7 and #8), the resolution and precision of the tomogram is limited in the lower area of the cross section.
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A calculation of the section modulus (based on second moment of inertia) for all load directions shows that relative strength loss due to decay is in a range of 30% in maximum.

For evaluating cross sections with decay, it has to be taken into account that location of decay is more important than size of decay. Big internal or central decay usually has a much smaller impact on strength loss than external decay. Strength loss due to internal decay is mostly much smaller than the loss of cross sectional area. More details on this aspect can be found in: "Basic Aspects of Mechanical Stability of Tree Cross –Sections." Arborist News Feb 2011, pp. 52-54. (http://viewer.zmags.com/publication/41f74b67#/)
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Evaluation of wind load and tomographic measurements from Nov 2011

Strength loss in 5 tomographic cross sections of the standing tree
(ranging from 4m down-to 10cm above ground)
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Evaluation of wind load and tomographic measurements from Nov 2011

Due to these measurements, maximum strength loss arises up to 32% within the stem.
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Evaluation of wind load and tomographic measurements from Nov 2011

Estimation of load carrying capacity of the standing oak stem

Assuming a relatively low modulus of elasticity of 10'000 N/mm² (typical for oak is ~13'000 N/mm²), a bending strength of 90 N/mm² (typical for oak is 96 N/mm²), a wind load center in 10m height above ground, and the smallest measured diameter of the stem (~1.7m), in case of intact cross section this oak would be able to withstand a wind load of 20 Mega Newton Meter (20 MNm).

The worst case scenario of the wind load assessment estimated ~175 kNm. Thus the theoretical safety factor would be in the range of more than 100.

As the maximum reduction of cross sectional load carrying capacity was about ~32%, the safety factor of the actual tree would be still in the range of higher than 50, thus far away from the natural safety factor of young trees (between 4 and 5).

As shown above, the real wind load is much smaller than estimated by the worst case scenario, most probable by about 50% (or even more), this brings the safety factor to a correspondingly higher level.

Based on this safety factor approach, the probability of failure of the oak due to wind loading even with this amount of decay (~32% strength loss) would be much lower than that of young intact trees.

Thus there was no indication of any dangerously higher probability of failure of the stem.
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Evaluation of wind load and tomographic measurements from Nov 2011

Possible wind load reduction pruning

If the safety factor argumentation would not be accepted, a crown pruning of this extension would lead to a reduction in wind load of about 40% and thus bringing back the balance between cross sectional strength and wind load to more safety than the previous equilibrium (as if the cross sections had been totally intact).

From my point of view, such a pruning would not destroy the impression of an important mature heritage tree and natural monument.

Another advantage of this approach would have been that the more symmetric crown shape would have led to less torsional loading, what is commonly the most dangerous factor for trees because torsional strength is the weakest material property of wood.