A New German Benchmark for Tree Crown Support

By Andreas Detter

A Cobra crown support system uses dynamic features to allow for adaptive growth while providing support against fracture. Unless otherwise noted, all images courtesy of Andreas Detter

A new version of the German technical best practices for Tree Care Operations (ZTV Baumpflege) was released in January 2006 by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL, in English The Landscape Research, Development & Construction Society). This organization is similar to TCIA, PLANET and/or the ISA in the U.S., developing best practices in the "green" industry, including the arboricultural profession.

After roughly 15 years of experience with synthetic crown cabling in Germany, the new ZTV Baumpflege includes descriptions of the advantages that synthetic support systems can offer and explicit descriptions of when and how to install them. It is apparent that crown support utilizing ropes and belts still has a questionable reputation among many arborists outside Europe. The industry has been hesitant to adopt these new products and techniques, though in the U.S. and some other countries, both steel and synthetic cabling materials are acceptable for installation of crown support. In Germany, Austria and Switzerland, new "tree friendly" concepts and synthetic materials (belts and ropes) have almost completely replaced "traditional" steel systems.

A major impetus for change in the German tree cabling systems was the urge to avoid the invasive crown anchors used in the installation of steel systems. New methods utilizing straps or belts and ropes were introduced to hold limbs and stems rather than bolting them. The thinking was that in trees that are compromised by decay (and those are the ones that arborists often cable), the perforation of CODIT (compartmentalization of decay in trees) walls by drilling and bolting may speed up the spread of decay at the installation points. Consequently, the ZTV Baumpflege now describes invasive crown support systems as an exceptional measure, with non-invasive alternatives being the preferred practice. When discussing the use of invasive crown anchors, the document only refers to bolts with eyes and counter screws (through-bolts). J-lags, though still widely used in other parts of the world, do not meet German best practices.

Decay around a through-bolt in lime (Tilia spp).

Low-load oscillation

The introduction and use of dynamic ropes instead of rigid steel cables created other opportunities to adapt crown support systems to the requirements of swaying, self-adapting trees. The phenomenon of adaptive growth or thigmomorphogenesis was studied extensively in the 1970s and '80s and still keeps researchers busy today. Experts all over the world monitored plants' reactions to mechanical stimulation and the ability to alter their load-bearing organs according to prevailing stresses.

A dynamic cabling system that allowed for low-load oscillations in moderate winds but prevented fractures during strong gusts was introduced by Wessolly & Vetter in Germany in the early '90s (Wessolly & Vetter "Kronensicherung in Bäumen [crown support in trees]" 1995). The product consists of a synthetic rope with moderate stiffness and a specific insert that allows for a defined amount of stretch at loads ranging up to 500 kg (1,100 lbs). This basic flexibility is independent of the length of the rope – an important difference from other dynamic systems, where stretch results only from rope elongation. After the concept was introduced, other products appeared on the international market that also used dynamic features to allow for adaptive growth while providing support against fracture. (photo oppostie, top)

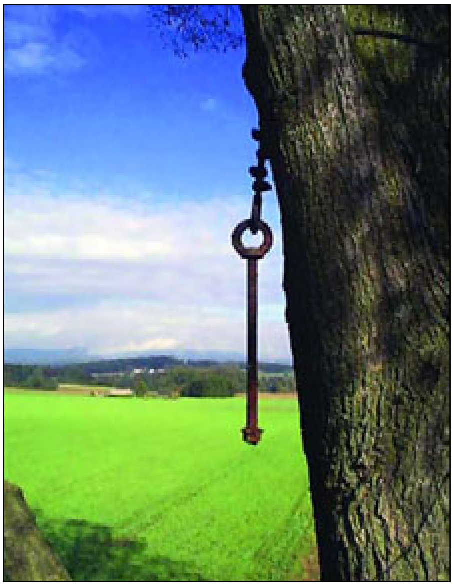
It is important to recognize that some slack in a cable does not necessarily result in a lot of play for the secured stems. Geometrical analysis indicates that even 8 inches (20 cm) of slack in a 13-foot (4 m) cable will only allow the cabled stems to move apart by roughly 1 inch (2.5 cm) before the cable becomes loaded. Steel cables are usually installed with even less slack. Trees then may incorporate this rigid connection into their load-bearing structure. Experience shows that suppressing oscillations and eliminating any bending stresses in the secured limbs may reduce the eventual compensation of structural weaknesses by means of adaptive growth. Without the stimulus resulting from sway in moderate wind, trees are less likely to develop reaction wood.

Shock absorption

The second feature of dynamic systems is a dampening effect. With sufficient flexibility in the cables, wind energy is dissipated more effectively in the tree crown as the natural swaying movements are limited but not completely suppressed. The use of shock absorbers (that also ensure low-load oscillation) reduces peak loads in the installation. In one experiment, when a dynamic crown support system was equipped with the specified shock absorber, a 20 percent reduction was recorded in peak loads generated from a dropping mass. Thus, dynamic properties help to save material and avoid hazards resulting directly from the installation of tree support systems.

The so-called "karate-effect," for example, was repeatedly observed in the failure of rigidly cabled tree crowns in the past and described by Wessolly & Erb (Handbuch der Baumstatik + Baumkontrolle [Manual for Tree Statics and Tree Inspection] 1998). Two leaders in a mature tree crown may sway when excited by strong wind gusts. Every now and then they may actually approach each other and then swing back in the opposite direction. A rigid steel cable attached to those two leaders will stop the movement abruptly, and the resulting shock load could overload and break one of the leaders a short distance above the crown anchor (very much like a karate fighter's quick stroke may break a stone). The fact that through-bolts or J-lags might have enhanced the spread of decay at the installation points contributes to the likelihood of fracture or "pull-out failure" of bolt or lag.

Failure due to the karate-effect.

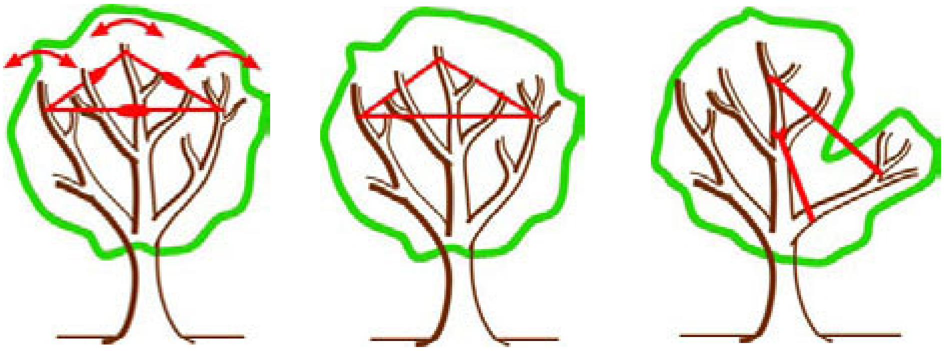


Pull-out failure of a through-bolt.

Durability

One frequent concern expressed about synthetic support systems is the potential for strength loss due to degradation in an adverse environment. Tests conducted on cables after five years of exposure in tree crowns indicated an average strength loss of 10 percent for a system made of black monofil polypropylene. The new German best practice requires manufacturers to guarantee the integrity of their products for at least eight years after installation. The required properties of strength and flexibility should not change significantly under the influence of humidity, sun exposure and temperature during this time. After eight years, the installation height should be reconsidered anyway, at least in vigorous trees with strong growth, in order to maintain adequate performance of the crown support system.

Manufacturers now recommend using stronger systems or they have changed the tensile strength of their products in order to compensate for future strength loss. During their lifetime, synthetic crown support systems should be inspected regularly from the ground to detect strength loss resulting from mechanical damage, overloading or constant tension, just as the steel systems should. Routine cable inspections should be undertaken every one to three years as a part of regular tree inspections, depending



Types of cabling according to ZTV Baumpflege. (courtesy Wessolly "Kronensicherung in der ZTV [Crown support in the ZTV]" 2006)

on the site, age and condition of the tree. Mechanical damages on rope due to abrasion reduced the tensile strength of a polypropylene rope in one case by one-third – an indication of how essential it is to avoid friction between the bark or small branches and synthetic cables.

Pruning vs. crown support

Crown support systems can be a useful alternative to pruning, but they are not always a better solution. As an example, lateral branches that extend horizontally beyond the actual perimeter of the crown are more prone to failure due to lateral gusts or gravitational loads. Cables can be installed to support such weak branches, but the installation will not correct the fault. In those cases, pruning could be a better option, or a combination of cabling and pruning could be considered.

Some crowns simply don't offer suitable anchor points to prevent failure. In those cases only pruning would be effective. In the long term, the eventual negative impacts of crown reduction on a tree's vigour should also be taken into consideration when proposing such a pruning strategy. In other cases, the installation of dynamic crown support systems allow for preventive measures to be taken that do not involve large pruning cuts, do not change the tree's appearance, and do not lead to a sometimes permanent reduction of photosyntheticly active crown mass.

Cabling systems

Usually, the goal of dynamic cabling is to retain enough flexibility in the crown to allow for the formation of reaction wood. Yet, in some cases, it may be essential to prevent any movement. The German ZTV Baumpflege 2006 distinguishes between three different types of cabling to support

Table 1: Empirical values for specifying dynamic cabling systems, according to ZTV Baumpflege 2006

Diameter of branch/stem measured at the time of installation at the base of the limb/branch	Minimum breaking load of the system for the certified work life, installation at a minimum of 2/3 of the length of the branch/stem to be secured
up to 40 cm (1.3 ft)	2.0 t (4,400 lbs)
40-60 cm (1.3-2 ft)	4.0 t (8,800 lbs)
60-80 cm (2-2.6 ft)	8.0 t (17,600 lbs)
over 80 cm (2.6 ft)	Exceptional; measures depending on the individual case

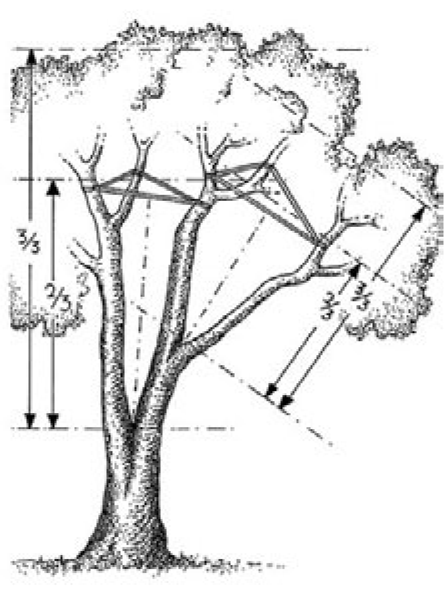
tree crowns. These systems differ in the materials used, their recommended strength and the mode of installation in the crown, depending on the type of weakness to be supported. They are:

- Dynamic failure-prevention systems
- Static failure-prevention systems
- Tethering systems

The standard type of crown support is designed and installed to prevent the fracture of limbs and stems in the crown. This goal can be achieved by effectively reducing the bending induced by wind gusts in order to avoid overloading of wood fibres or failure of crotches.

Dynamic failure prevention

The cable strength required to dampen a leader's swaying movement from the start is considerably less than the strength required to catch a falling limb or stop a stem once in excessive sway. As a comparison, it's not to hard to keep a child on a swing from gaining speed, but once he gets going back and forth wildly, stopping him can be dangerous. With dynamic systems, wind loads are counterbalanced by the restriction of movement due to cables. At the same time, small oscillations of the secured parts of the crown should be permitted when amplitudes are still low. In dynamic systems that offer enough flexibility, the whole tree structure, including trunk, limbs and cabling system, helps dissipate the wind energy. Peak loads are reduced due to stretch in the support system and dampening effects in the crown. Therefore, the required tensile strength is much lower than one might assume. In a study carried out on a 29 m (95 foot) tree in Australia, only 440 kg (970 pounds) were recorded as the maximum load in a dynamic cable over the period of one year (James, "An engineering study of tree cables," 2002).



A failure preventing system (Source: ZTV Baumpflege 2006, courtesy of FLL e.V.)

The height of installation is crucial for the success of dynamic cabling. Reported failures of synthetic crown support were often a result of low installation height and poor technical knowledge about modern systems. The installation point should be chosen at approximately two-thirds of the length of the secured crown part, just as recommended in the ANSI Standard A300. The basic idea is to counterbalance swaying forces in the crown at the very height where they are initiated. Many steel cable systems were installed too low or were outgrown by vigorous trees. In a special table (Appendix B of the ZTV Baumpflege), guidance is provided for the minimum tensile strength of dynamic systems based on the diameter of the limb to be secured. (Table 1).

Static failure prevention

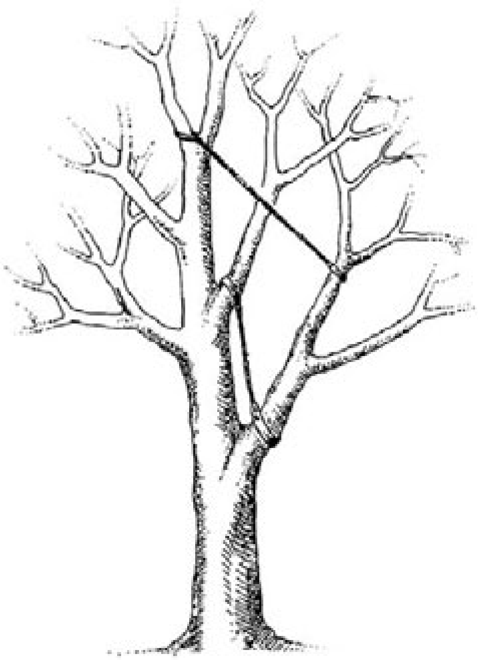
In exceptional cases, there may be a desire to keep special trees even though they have major structural defects. Tree support systems may be used to keep those trees over a limited period of time, despite their weaknesses. Static failure prevention systems are designed to immobilize limbs that are predisposed to or have experienced primary failure. In a broken crotch, for example, even the tiniest movement between newly formed wound tissues would cause the crack to propagate. In order to keep leaders absolutely still, German arborists use a combination of crown support using static low-stretch ropes and bolting the crotch. In those cases, even strong reductions could not sufficiently suppress movements in the crown as effectively as cabling would.

As a general rule, if the systems are designed for static failure prevention ZTV Baumpflege recommends doubling the tensile strength of the ropes in Table 1 and omitting the shock absorbing devices.

A crack in a V-shaped crotch indicates the need for static crown support.

Tethering systems

If sufficient safety against fracture can not be achieved with pruning, cabling or a combination of both measures, a special form of crown support might provide an alternative to removal. The German best practice introduced the term "tethering system" for support systems that are designed to barely prevent limbs from reaching the ground and causing damage in case of failure. Those systems should:



A tethering system with two cables (Source: ZTV Baumpflege 2006, courtesy of FLL e.V.)

"[…] only be used under special circumstances where a reduction of the branch in question is not possible or not desired" (ZTV Baumpflege 2006).

Tethering systems should be installed more or less vertically to avoid long distances of fall and to minimize shock loading. The forces generated by a free-falling limb would exceed the load-bearing capacity of many synthetic ropes. Even if steel cables and bolts in a traditional support system were able to sustain such peak forces, limbs serving as anchor points in the tree may not. Therefore, it is important to note that those support systems are not designed to catch falling limbs, but rather to support and hold them when fracture is initiated by strong deflection. The recommendations for tensile strength of those systems take into consideration the inevitable peak load generated when a limb actually breaks and is being stopped by the support system.

Types of connections

ZTV Baumpflege 2006 proposes three basic types of connections: a direct connection, a triangular or network configuration, and a box or ring-shaped connection. Utilizing these connection types, arborists can design a support system that considers the existing crown structure and the goals to be achieved by cabling.

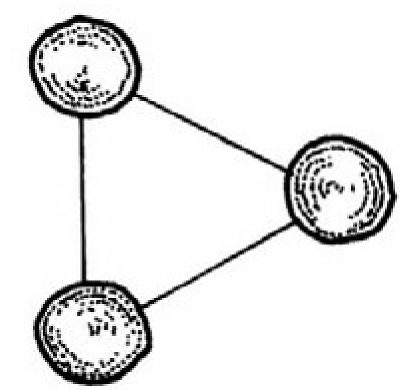
Securing two leaders or stems with one direct cable will only serve as a back-up against overloading in the direct line of the connection. Lateral swaying (torsional or twisting motions) of the secured crown parts cannot be prevented with a single connection. Therefore, this type of connection is mainly used for tethering systems and in very confined crown structures. Securing a compromised tree to an adjacent tree is also often carried out using a direct connection. However, it is strongly recommended to try to utilize other parts of a tree crown to create triangular cabling configurations.

The triangular system is a very stable form of cabling that offers support for the secured part of the crown against more than one direction. Therefore, when branches and stems have to be connected, a system of one or more triangles is installed to form a network that reduces swaying in several directions. This installation mode also serves to dissipate wind energy and helps minimizing the loads at the anchor points and in the cables. Box or ring-shaped connections without diagonal connections are only used in exceptional cases, where mainly lateral swaying forces are to be absorbed, e.g. in secondary crowns with strong re-growth.

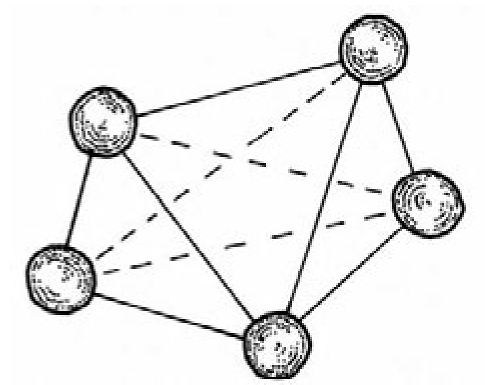
Table 2: Recommended tensile strengths for tethering systems, according to ZTV Baumpflege 2006

Diameter of branch/ stem measured at the time of installation <u>at branch collar/ stem base</u>	Minimum breaking load of the system over the period its service is guaranteed, (at least for a period of 8 years)
up to 30 cm (1 ft)	2.0 ton (4,400 lbs)
30-40 cm (1-1.3 ft)	4.0 ton (8,800 lbs)
40-60 cm (1.3-2 ft)	8.0 ton (17,600 lbs)
60-80 cm (2-2.6 ft)	16.0 ton (35,200 lbs) *
over 80 cm (2.6 ft)	Exceptional; measures depend on the individual case

* Instead, two tethering systems may be installed with a breaking load of 8.0 t each.



Triangle (top) and triangular network (below) configurations (Source: ZTV Baumpflege 2006, courtesy of FLL e.V.)



Limitations

Trees are naturally at risk of failure during gale force or near gale force storms. No crown support system will be able to eliminate hazards completely from a living and wind-exposed tree. Therefore it must be clearly stated and understood that best practices for new techniques can only serve as a guideline and help to promote development in arboriculture, but will never lead to absolute safety against failure.

Andreas Detter is a consulting arborist and co-founder of Brudi & Partner TreeConsult in Gauting, Germany, which coordinated the refinement of the ZTV Baumpflege 2006 into English. This article was excerpted from his presentation on German cabling best practices at TCI EXPO 2006 in Baltimore. *The author would like to thank Phillip van Wassenaer, Mississauga, Canada, who contributed greatly to this publication, and Mike Neuheimer, Windsor, Canada, for his work on the translation of the ZTV Baumpflege 2006, which will soon be available in English. Please check www.tree-consult.org for links or inquire directly at www.f-l-l.de.*