Tree Crown Support

New German Standards for Tree Care
“ZTV Baumpflege”, edition 2006

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1. Introduction

The Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) e. V. or The Landscaping and Landscape Development Research Society is a German Registered Association, and is the research group for best practices in the "green" industry. This research group also includes the arboricultural profession. Regulations and standards published by this organization are the result of numerous research groups working together to develop and improve all aspects of the landscape industry. The new version of the German technical standard for Tree Care Operations (ZTV Baumpflege) was released in January 2006. The FLL supported the translation of the standards in order to facilitate comparisons to standards in other countries. The initial translations have been refined by an international group of tree care experts coordinated by Brudi & Partner Tree Consult.

After roughly 15 years of experience with synthetic products, discussion arose among German arborists and tree care experts about the accuracy of existing standards for the installation of cabling systems in potentially hazardous tree crowns. The new edition of the ZTV Baumpflege contains revised specifications for synthetic crown support systems. The standard includes descriptions of the advantages that synthetic systems can offer, why the systems are installed and explicit descriptions of when and how to install them. By inviting several experts to contribute to the discussion and by incorporating the principles of tree statics, tree dynamics and tree biology, some essential issues have been clarified.

It is apparent that crown support systems utilizing ropes and belts still have a questionable reputation among many arborists outside of Europe. The industry has been hesitant to adopt these new products and techniques. In the US and other countries worldwide, tree support using lags, bolts and steel wire cables is still the standard practice. In the early 90's, a time when the German view on trees and tree hazard mitigation was undergoing numerous changes, new "tree–friendly" concepts were developed for crown support systems. In Germany, Austria and Switzerland, synthetic materials (belts and ropes) have now almost completely replaced the "traditional" systems.

2. Synthetic Crown Support Systems

2.1 Non-invasive Installation

The main impetus for change in the German tree cabling systems was the urge to avoid the invasive crown anchors used in the installation of traditional steel systems. New methods utilizing straps or belts and ropes were introduced to hold limbs and stems rather than bolting them (Sinn 1989, Schröder 1993). The thinking was that in trees that are compromised by decay (and those are the ones that arborists often cable) the perforation of CODIT walls by drilling and bolting may speed up the spread of decay at the installation points (comp. later publications of Stobbe 2000, and Kane, Ryan 2002).

Consequently, the German technical standard now describes invasive crown support systems as an exceptional measure, with non-invasive alternatives being the standard. When discussing the use of invasive crown anchors, the standards only refer to bolts with eyes and counter screws (through-bolts). J-lags, though still widely used in other parts of the world, do not meet the German standard.

2.2 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 trees, i.e. the swaying, self-adapting structures that they are being used in. The phenomenon of adaptive growth was studied extensively in the 1970's and 80's 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 the prevailing stresses. This ability was termed thigmomorphogenesis by Jaffe (1973) or adaptive growth (comp. Telewski, Jaffe 1981, Ennos 1995).

A dynamic cabling system that allowed for low-load oscillations in moderate winds but prevented fractures during strong gusts was introduced in Germany by Wessolly and Vetter (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 kp (1,100 lbf). This basic flexibility is independent of the length of the rope – an important difference from other dynamic systems, where stretch results only from the rope's flexibility. After the concept was introduced, other products appeared that also used dynamic features to allow for adaptive growth, while providing safety against fractures.

It is important to recognize that some slack in a cable does not really result in a lot of play in the secured stems. Pure geometrical analysis shows that even 8'' (20 cm) of slack in a 13 ft (4 m) cable will only allow the cabled stems to move apart by 1'' (2.5 cm) before the cable becomes loaded (Detter 2004). Steel cables are usually installed without any slack. Trees then will incorporate this rigid connection into their load-bearing structure. Experience shows that suppressing oscillations and eliminating any bending stresses in the secured limbs prevents the eventual compensation of structural weaknesses by means of adaptive growth. Without the stimulation of movement, trees are less likely to grow reaction wood (Leiser et al. 1972).

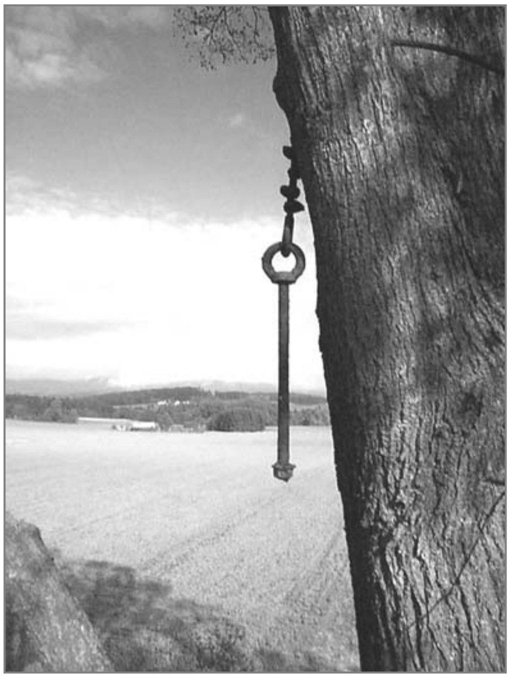
2.3 Shock Absorption

The second feature of dynamic systems is a dampening effect. With more flexibility in the cables, wind energy is more effectively dissipated in the tree crown as the natural swaying movements are reduced but not completely suppressed. The use of shock absorbers (that also ensure lower load oscillations) effectively reduces peak loads in the installation. In one experiment, when a dynamic crown support system was equipped with the specified shock absorber, a 20% reduction was recorded in peak loads generated from a dropping mass (Detter 2003). Thus, dynamic properties help to save material and to avoid hazards resulting directly from the installation of tree support systems.

Wessolly & Erb (1998) described the so-called "Karate-effect" that was repeatedly observed in the failure of cabled tree crowns in the past. 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 away from each other in the opposite direction. If a rigid steel cable attaches those two leaders, the steel cable will stop this movement abruptly, and the resulting shock load could overload and break one of the leaders a short distance above the crown anchor. The fact that through-bolts or J-lags can eventually increase decay at the installation points contributes to the likelihood of fracture above the attachment point or "pull-out failure" of bolt or lag.

Fig. 1: Failure due to "Karate-Effect"

Fig. 2: "Pull-out Failure" of a bolt



Also, to effectively reduce peak loads in cables, it is essential to have the cabling systems installed at the proper height above the weak area to be supported. The basic idea is to counterbalance swaying forces in the crown at the very height where they are initiated. Because many steel cables are installed far too low, much greater forces are generated from gusts and the swaying of tree crowns.

2.4 Durability

One frequent concern expressed about synthetic support systems is the potential for strength loss due to degradation in an adverse environment. The new German technical standard requires manufacturers to guarantee the integrity of their products for at least 8 years. The required properties of strength and flexibility should not change significantly under the influence of humidity, sun exposure and temperature.

Tests conducted on cables after 5 years of exposure in tree crowns indicated an average strength loss of 10% for a system made of black polypropylen (PPP monofil) and up to 50% for another product made from blackened polyethylen (PE) (Brudi 2000). Mechanical damages on the polypropylene rope due to abrasion reduced the tensile strength in one case by one third (Brudi et al. 1999) – an indication how essential it may be to avoid friction between the bark or even small branches and synthetic crown support systems.

For this reason 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 life time, synthetic crown support systems should be regularly inspected from the ground to detect strength loss resulting from mechanical damages, overloading or constant tension. Routine cable inspections should be undertaken every 1 to 3 years as a part of the regular tree inspections, depending on the site, age and condition of the tree (FLL (eds.) 2004).

3. 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 corrective pruning could be a better option, or a combination of cabling and pruning could be considered.

> "*The question that needs to be considered is whether the desired results can be achieved with crown pruning or by installing a crown support system, or alternatively by a combination of both.*" (ZTV Baumpflege 2006)

Some crowns simply don't offer suitable anchor points to prevent failure by installing a support system. 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.

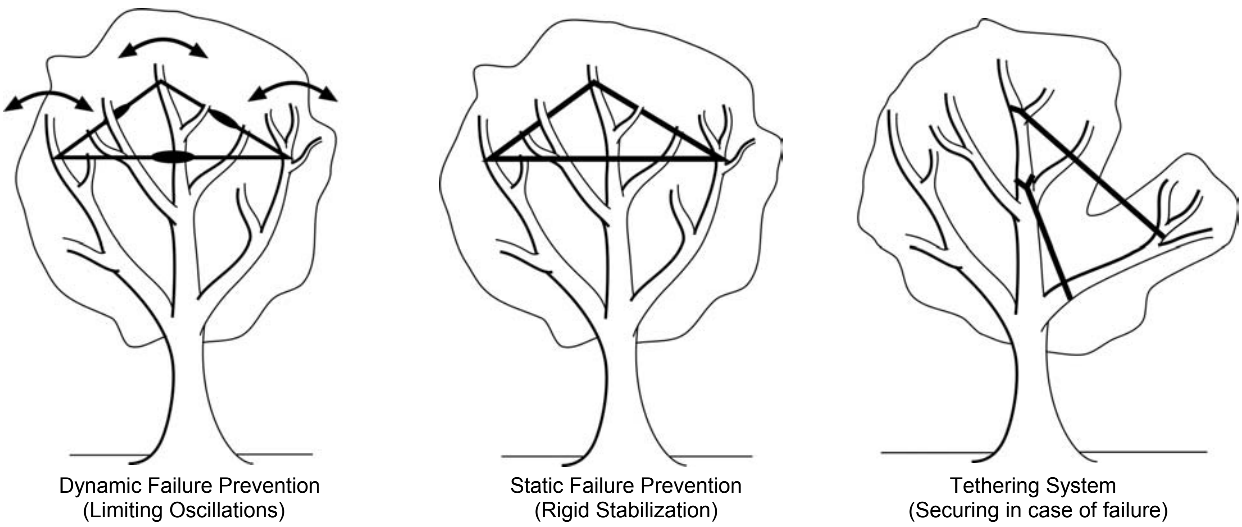
Usually the goal of dynamic cabling is to retain enough flexibility in the crown to allow for the formation of reaction wood. Yet, in some cases, it may be essential to prevent any movement. In a broken crotch, for example, even the tiniest movement between newly formed wound tissue would keep the crack from closing. In order to keep leaders absolutely at still, a combination of crown support using static low-stretch ropes and bolting the crotch may be the only choice. In those cases, even strong reductions could not sufficiently suppress movements in the wind.

4. Cabling Systems

The German ZTV Baumpflege 2006 distinguishes between three different types of cabling to support 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:

1. Dynamic failure-preventing systems
2. Static failure-preventing systems
3. Tethering systems

Fig. 3: Three modes of cabling to support tree crowns (comp. Wessolly 2005)



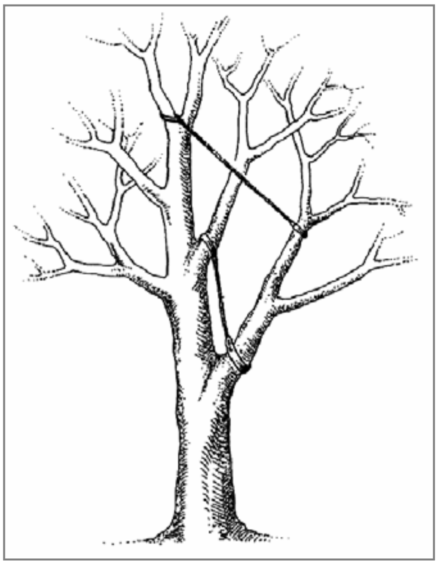
4.1 Tethering Systems

If sufficient fracture safety can not be achieved with pruning or cabling or even a combination of both measures, a special form of cabling might offer a solution. The new German standard introduced the term "tethering system" for a crown support system that is designed to prevent limbs from reaching the ground if they fail. Those systems should

> *"[…] 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 fall distances and to minimize shock loading. As a general rule, static systems should be used. The basis for cable specifications is the weight of the crown part that the system is supposed to hold in case of a failure. In a special table (Appendix B of the ZTV Baumpflege), guidance is provided for the minimum tensile strength of these systems based on the diameter of the limb to be secured. Those figures also take into consideration additional loading by the inevitable peak load that occurs when a limb actually breaks and is being gradually stopped by the support system.

Fig. 4: a tethering system with two cables



source: ZTV Baumpflege 2006

The forces generated by a free falling limb could exceed the load-bearing capacity of many synthetic ropes. A limb weighing 1 ton (2,200 lbs), free falling from his position in the crown, could easily create a shock load of several times its weight if stopped by a length of rope. Even if steel cables and bolts in a support system were able to sustain such peak forces, many limbs serving as anchor points in the tree would 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 (that could not be prevented by other cables or pruning).

Table 1: Recommended tensile strengths for tethering systems, according to ZTV Baumpflege 2006

Diameter of branch/ stem measured at the time of installation at branch collar/ stem base		**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 t (4'400 lbs)
30-40 cm	(1-1.3 ft)	4.0 t (8'800 lbs)
40-60 cm	(1.3-2 ft)	8.0 t (17'600 lbs)
60-80 cm	(2-2.6 ft)	16.0 t (35'200 lbs) *
over 80 cm	(2.6 ft) Exceptional; measures depend on the individual case	

* Instead, 2 tethering systems may be installed with a breaking load of 8.0 t each.

4.2 Failure Preventing Systems

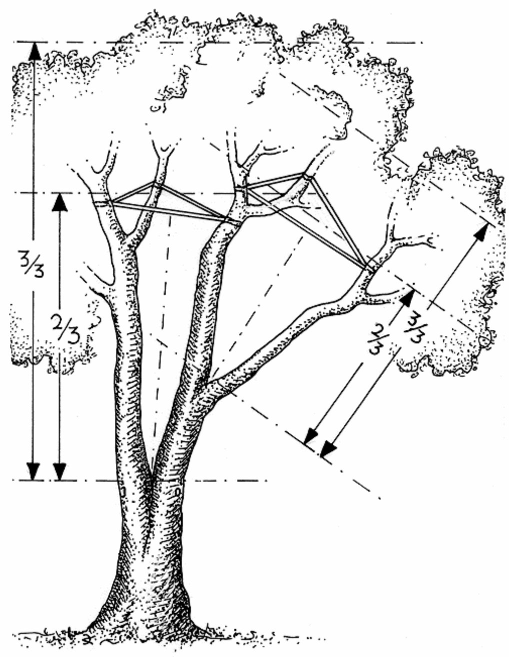
The standard type of crown support is different from the one just described. It is designed and installed to prevent the fracture of limbs and stems in the crown. This goal can be achieved by effectively reducing the bending of the stems by wind gusts and therefore avoiding compression failures or delamination cracks in limbs and crotches.

4.2.1 Dynamic Failure Prevention

The cable strength required to stop a leader from over-oscillating is much less than the strength required to hold an already broken and falling limb. In dynamic systems that offer enough flexibility the whole tree structure including the trunk, limbs and cabling system help to dissipate the load. Peak loads are reduced due to dampening effects and strain in the system. Therefore trees can withstand even greater gusts of wind without generating excessive tension in cables and eventually breaking them.

The height of installation is crucial for the success of dynamic cabling. 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 A 300 (ANSI Standard A 300). With dynamic systems, wind loads that affect the crown are counterbalanced by the restriction of movement due to cables. At the same time, oscillations of the secured parts of the crown should be permitted when amplitudes are still low. As a rule, cables should be installed more or less horizontally. In some cases, for example where the anchoring leader has a smaller diameter than the compromised (supported) one, angling the cable to shorten the lever is advantageous.

Fig. 5: a fracture preventing system



source: ZTV Baumpflege 2006

Provided arborists adhere to the recommended installation height, the required tensile strength is much lower than one might assume. As a comparison, it's not to hard to keep a kid on a swing from starting to swing, but once they get going back and forth, stopping them can be dangerous to everybody involved! Reported failures of synthetic crown support were often a result of low installation height and poor technical knowledge about modern systems.

Table 2: 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
40-60 cm	(1.3-2 ft)	4,0 t
60-80 cm	(2-2.6 ft)	8,0 t
over 80 cm	(2.6 ft) Exceptional; measures depending on the individual case	

The data contained in Table 1 and 2 is supported by different engineering approaches presented by Wessolly (2005). This arithmetical evaluation of the proposed strength of synthetic cables is based on field data on the size and weight of a great number of branches and limbs.

4.2.2 Static Failure Prevention

In some exceptional cases, there may be a desire to keep special trees despite the fact that they have major structural defects. In these cases tree support systems can be used to keep the trees safe despite their weaknesses. For example, trees with V-shaped unions, included bark and cracks can sometimes be kept for a period of time instead of removing them. In those rare cases, the increased stiffness that comes along with the greater tensile strength of a static system is not a disadvantage for the tree's long term development (as it would be in the dynamic securing mode). If the tree was not properly secured, removal would be the only option.

Static failure prevention systems are designed to immobilize limbs that are predisposed to failure. Therefore, high-performance synthetic fibers or even steel cables can be utilized. As a general rule, ZTV Baumpflege recommends doubling the tensile strength of the ropes in Table 2 and omitting the shock absorbing devices if the systems are designed for static failure prevention. In these types of trees German arborists also use bolts (braces) to stabilize a broken crotch and through-bolts in parts of the crown that are not affected by decay. The ZTV Baumpflege contains specifications for bolting various sized limbs, but j-lags are not even discussed.

5. 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 three connection types, the arborist can design a support system that considers the existing crown structure and the goals to be achieved by cabling. The ZTV Baumpflege 2006 defines the objectives of different types of connections as follows:

> *"Crown securing systems can be installed:*
> - *to secure individual branches/stems (single-limb connection)*
> - *to secure several branches/stems with or without forming a network*
> - *to incorporate neighbouring trees in a network(in special cases)"*

5.1 Direct Connections

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 can not be prevented with a single connection. Therefore this type of connection is mainly used for supporting/ holding systems and in very confined crown structures. Securing a compromised tree to a neighbouring 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.

5.2 Triangular Configurations and Networks

The triangular system is a very stable form of cabling that offers support for the secured part of the crown in 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 to several parts of the crown through the cables, and helps to minimize the loads at the anchor points and in the securing connections themselves.

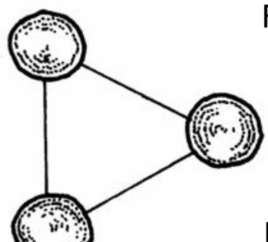


Fig. 6: Triangular Configuration
between three branches/ stems

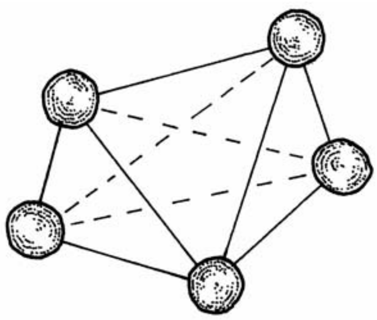


Fig. 7: Triangular Network
between five branches/ stems

– – – – possible additional or alternative connections

source: ZTV Baumpflege 2006

5.3 Box or Ring Combinations

In a ring-shaped combination the diagonal connections found in the triangular connections are missing. These systems should be installed when only lateral swaying forces are to be absorbed. This type of combination offers good opportunities to avoid excessive pruning especially in secondary crowns and when securing regrowth that occurs after topping.

6. Limitations

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

> *"It must be explicitly expressed, that a 100% guarantee that limbs will not fail with the use of cabling systems and/or pruning is not possible." (FLL 2006).*

The German Standard for Tree Care, ZTV Baumpflege 2006, will soon be available as a full English translation on the internet. Please check our website www.tree-consult.org for links or inquire directly at www.fll.de.

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