cobra®

TREE CABLING SYSTEM

A Brief Guideline Of Tree Cabling

Publisher:

pbs Baumsicherungsprodukte GmbH
Gerokstaffel 1
70184 Stuttgart
Germany

Phone: +49-(0)711-235661
Fax: +49-(0)711-235662
E-mail: pbs@cobranet.de
Web: www.cobranet.de

Editor:
Graduated Engineer of Landscape Planning Jörg Wohn

Edition:
April 2011

Printed in Germany

Content

1. Foreword

This Guideline explaines the state of the art and the correct use of tree cablings. Beside it gives a short glimps on the background of tree cabling development.

The interested user will be shown what is importend in tree cabling and what possibilities a modern tree cabling system offers as well as the limits of will be mentioned. Beside of the correct use of tree cablings it is importend to know how this spezialized part that supports modern tree care has been developed. Therefor it is necessary to take a look at the history of tree cabling and the experiences earned during the past and which were integrated in serveral standards worldwide.

Without any fundemental knowledge of tree biologie and tree mechanics and without any theoretical knowledge nor tree cabling can be installed professionally. For this reason in the following chapters the primary knowledge will be exlained briefly. To soldify one's knowledge hints for more detailed information and sources will be given.

Equiped with those basics installation guidelines can be comprehended logically and installation situations can be assessed much better.

But in a tree anything seems to be much mor ecomplicated and the optimal situation often is not given. This guideline should help to handle the individual situation of a tree maybe with improvisation but always profesionally.

As it is be known, experts are not made in a day. Even so-called professionals had to begin with the most elementary steps. Only practice makes perfect – and of course the exchange with collegues.

For this reason we want to pass our knowledge and experience to our customers and arborists. Finally we should learn from each other to broaden our knowledge of trees and improve our exposure to trees.

2. Trees And Their Static Attributes

2.1. Wood – A Living Construction Material

Trees are living and with their wooden body it is possible for them to suite themselves to the environmental surroundings in the course of time. For example depending on the depth of the soil they root deep or flat and strenghten their trunks and branches with compession wood and tension wood in the prevailing wind direction.

Naturally only a vital tree can staticlly optimize itself by accrescence and hence better its stability and break resistance. A weakend tree will sooner or later lose the balance between building up wood and the reduction of wood (e.g. through decay). As result it increasingly gets unstable.

2.2. A Brief Treestatical Explanation

As mentioned trees never grow aimless and associated with the attributes of living wood[1] the following statical statements[2] can be made.

- double diameter = eightfold load transfer repectively eightfold load capacity
- half diameter = 16-fold formability

If the load capacity or formability gets exceeded it comes to failure. Here two failuretypes can be differenciated

.

- Primary Failure = Passage between elastic (reversible) and plastic (irreversible) deformation
- Secondary Failure = After plastic deformation it comes to upsetting deformation and finally to breakage

How these statements are presented in practice will be subsequent described.

[1] see WESSOLLY, 1992: “Material- und Struktureigenschaften der Bäume – Fortschreibung des Stuttgarter Festigkeitskatalogs“

2.3. The Trees Stragety For Growth

2.3.1. Primary Growth

In competition with its neighbours the offspring has quckily to grow upwards so that it can assert a place in the sun. By that primary growth it gets a very slim and excalted habitus. Therewith the load capacity is insufficient (see above) likewise its formability is very high. On the one hand this habit is necessary to survive inside a grove and on the other hand it is the only place where this habit is possible because the neighbours protect on another against windloads. Nevertheless young trees have to keep their stability somehow. What keeps them upright is called...

2.3.2. Prestressing

Younger trees have a certain prestressing inside that is stablizing the flexible and deformable wooden substance of their body in some degree similar to the human body tension.

2.3.3. Secondary Growth

Has the young and slim tree climbed up to the leafy canopy of its neighbours then it made it to strech out its leafes to the lifespendig sunlight. But now it is confronted with a new threat – the wind.

The wind is caught up in leafes and branches and lets them swing. To a certain extend this is not a problem for the tree. Since the tree has not to grow upwards anymore it can change its security strategy.

The place in the sun allows the tree better to convert sunlight by photosynthesis into starch. This assimilates are used by the tree for secondary growth to firm its branching wooden corpus. In spirit of: ‚The thicker a tree, the more secure and stable it is.'

2.3.4. Aftermath of secondary growth:

Secondary growth lets the cambium, the phloem (nutrient transport) and the xylem (water transport) move off from the center of the stem. The wood near the center of the stemm lignifies through the formation and deposit of lignin in cell walls and builds the so-called heartwood. This does not serve the nutrient and water transport anymore but serves very well as static carrying structure.

As well through secondary growth the early roots of the tree become cut off the xylem and phloem. Without function they die like the heartwood above. Due to the soil conditions the died of roots begin to decay. By-and-by the decay conical moves upwards into the stem. As long as the tree is vital it is no problem because it growth at least as fast to the outside as it decays inside. It is safe to say: ‚Nearly all old trees have a decay inside their stem foot.'

2.4. The V-Shaped Crotch – A Naturally (Genetical Caused) Weakness

Some trees have genes that let them form unstable V-shaped crotches. Certainly the species is importend by this means but also within a species there are individuals that conspicuously often form statically critical crotches.

Because of its forming the following problems may occure. Therefor and in correlation with tree security analysis V-shaped crotches have to be given a particular attention.

The wood fibres of a V-shaped crotch run almost exclusivly parallel and do not form a good conection between the branches. In opposite the wood fibres inside a U-shaped crotch are twisted and forming a stable connection and transfering load very well.

It also comes along that the basic approche of the branch is smaller in diameter than the proper branch. As mentioned above half diameter means one eighth of load capacity that means a V-shaped crotch can withstand less load than the branch and often result in failure.

By-and-by the secondary growth is pressing the close to each other standing branches together. Thus the bark between the branches ingrowth. The connection of the parallel running wood fibres get even worse. The tree ‚notices' this weakness and begins building up compensation wood. Well shaped the compensation wood looks like ‚ears' on the both sides of the crotch.

To secure such statically critical crotches tree cabling systems can be used.

fig. 1 Cracked V-Shaped crotch with different diameters

3. A Brief History Of Tree Cabling

3.1. Steel Cabling

3.1.1. Approach and technique

Since the 1960th steel cables were used in trees to stabalize them. Therefore first the branches were drilled through and threaded bars and ring nuts were installed. Then a steel cable was thighten between.

3.1.2. Load capacity

But the load capacities of the single parts were not equal. So the steel cable could hold 7 tons but the connection between threaded bar and ring nut only approxamately 1 ton. But „a chain is only as strong as its weakest link“ so the load capacity of a steel cabling is 1 ton not 7 tons.

3.1.3. Troubles and subsequent injuries

Nevertheless since the 1960th serveral 10.000 steel cablings were installed in trees. In spite of high impact shocks and a low load capacity of ‚only' 1 ton no case is known in which a ring nut failed. But steel cable failed for some other reasons:

- they rusted through and afterwards hang loose in the tree
- theiy caused decay in branches due to drilled through branches
- they ingrowed and thus weakend the branches
- the counter bearing could collaps due to a high impact shock
- after installing the steel cabling the secondary growth occur only above the cabling and causes a loss of stability (see above ‚half diameter means one eighth of load capacity')

3.1.4. Summary

Finally the largest disadvantages of steel cabling can be summerised as follows:

- Steel cablings mostly wounded the trees (e.g. drilling and ingrowing)
- Steel cablings are static systems that preventing the movement of branches and hence stopping secondary growth below the cabling that led to a loss of stability
- Steel cablings causing high impact shocks that may led to injuries or in the worst case to counter bearing failure

fig. 2 Steel cabling drilled through a branch

fig. 3 Ingrown steel cabling an growth-deficit

3.2. A New Tree Biology

At the end of the 1970th Dr. Shigo's study of tree biology[3] led to a new thinking within the arboriculture. Thus the critical analyzing of existing techniques in pruning and cabling trees started. More and more the trees were seen from a different angle and arborists began to speak about wounded trees not any longer about damaged trees. Also it were understood that the trees organism reacts different than the organism of human beings or animals. Trees do not heal injured material like a skin does they are sealing the wound through the process of ‚compartmentalization'[4].

3.2.1. The search for new cabling techniques

As mentioned above the new understandig of tree biology led to the search for a new technique of cabling to avoid the known troubles and disadvantages of steel cablings. The new cabling system arborists were looking for should offer the following solutions for the mentioned problems.

- injury-free installation in trees
- enough dynamic to enhance the branches ability of self-training thru secondary growth
- good durability and satisfying service life
- reducing impact shocks
- avoiding of ingrowth
- enough tensile strength to prevent branches from failure

In the early 1990th the idea of using sythetic cables instead of steel cables to develop dynamic tree cabling systems came up. But still many practical obstacles had to be daffed aside.

[3] DR. ALEX SHIGO, 1989: ‚A New Tree Biology', Shigo & Trees, 132 pages
[4] see DR. ALEX SHIGO ‚Compartmentalization Of Decay In Trees (CODIT-Model' explained in ‚A New Tree Biology'

4. cobra – A Modern Dynamic Tree Cabling System

In 1992 during the development of cobra all the problems and disadvantages of steel cablings were well-known and were considered. For this reason cobra was the first tree cabling system succeeded in overcoming all the difficulties. And all of its parts are elaborated and have a specific function within the system. In the following chapter all those parts and the important criterias when developing them will be explained.

4.1. The Cable

The essential part of a tree cabling system is the cable. The decision which cable or material is best for a tree cabling system has to be well thought-out because it has to fullfil a lot of tasks. It will have to...

- connect two branches.
- allow movement during gentle winds.
- support the branches during storms.
- have enough tensile strength to resist the windloads.
- resist destructiv environmental effects, e.g. UV-rays and acid rain.
- reduce the impact shocks.
- do all this for servral years during installed in a tree.

4.1.1. The material

There are many different synthetic materials that can be used as a tree cable and they all have different characteristics. There is only one principal that is true for all synthetic materials – they are all ageing. But even here they behave very different. Here is a short overview of the three shynthetic fibres mostly used for tree cablings.

Material	Polypropylene (PP)	Polyester (PES)	Polyamid (PA)
Fibre Typ	monofile	multifile	multifile

Elongiation At Break	13 – 17 %	10 – 17 %	18 – 24 %
UV-Resistance	Sufficent	excellent	good
Resistance To Acid	Excellent	Good	good
Resistance to Alkalis	Excellent	Good	average
Creep	At high loads	Hardly messurable	slight creep
Melting Point in °C	175 °C	225 °C	215 °C

fig. 4 Overview: Material characteristics of PP, PES and PA

The material used for the cobra cable is blackened polypropylene (to blacken a synthetic cable is the best way to improve its UV-resistance).

fig. 5 Cable cobra plus 2 t

At the first glimps polypropylene seems to have a worse UV-resistance than polyester and polyamid. But the polypropylen monofils are thicker than the multifils of polyester or polyamid and therefor monofils having a better surface-mass-ratio. That means the surface that is affected by UV-rays and acid is less. The result is that the durability of polypropylen monofils is better than the durability of the multifils of the other materials. Also it is to mention that polyamid shrinks around 10 % and loses 10% - 30 % of its load capacity if getting wet.

The durability of different tree cabling was analyzed by Mrs SPIESS, Mr BRUDI and Dr LESNINO in a study of the University of Weihenstephan[5] (near Munich). The result of this study is that the polypropylene used for the cobra cables have lost less than 2 % of its load capacity each year. Compared with the polyester and polyamid – both lost around 10 % each year – the durability of cobra tree cablings is excellent.

4.1.2. The necessary tensil strenght

The requirements of tensil strenght depends on the windloads (in installation heigth of the tree cabling) dedicated to push a healthy branch far enough to break it. Considering that the occuring windloads have to be less the load capacity of a branch a dynamic tree cabling system must primarily bypass the windloads from a injured branch to a healthy branch. Particularly a injured branch is still involved in the load transfer.

As mentioned above in the early 1990th arborists had nearly 40 years of experience with steel cablings with a load capacity of approximately 1 ton (see above ‚Steel Cabling').

Considering all this and with the additional practical experiences collected since 1992 the load capacity of dynamic tree cabling systems should be as shown in the table below.

Basis Diameter Branch/ Stem	Minimum Tensil Strength Of A Dynamic Tree Cabling
up to 40 cm	2 tons
up to 60 cm	4 tons
up to 80 cm	8 tons

fig. 6 Minimum tensil strength of a dynamic tree cabling

Besides the use as a dynamic tree cabling cobra can be used as a static tree cabling and as load-/ support cabling.

To reach the necessary stiffness for static tree cabling or support cabling a higher tensile strength have to be choosen. Thereby the load capacity of the cable gets (percentage) less stressed and the cabling gets less streched. This makes it also possible to use synthetic cables under constant load, e.g. the plastic deformation of cobra starts at a constant load of 80 % of the cables tensil strength. According the German Tree Care Guidelines (ZTV Baumpflege, 2006) for a static cabling, at the same branch diameter, a cable with the double tensile strength has to be choosen, compared with a dynamic cabling.

Basis Diameter	Minimum Tensil Strength Of

[5] see SPIESS, BRUDI, LESNINO, 1999: ‚Erfolgskontrolle des cobra-Kronensicherungssystems'

Branch/ Stem	A Dynamic Tree Cabling
up to 40 cm	4 tons
up to 60 cm	8 tons
up to 80 cm	16 tons

fig. 7 Minimum tensil strength of a static tree cabling

Basis Diameter Branch/ Stem	Minimum Tensil Strength Of A Dynamic Tree Cabling
up to 30 cm	2 tons
up to 40 cm	4 tons
up to 60 cm	8 tons
up to 80 cm	16 tons

fig. 8 Minimum tensil strength of a load-/support tree cabling

4.1.3. Ageing reserve

Since synthetic cables are ageing and thus losing a bit of their tensile strength every year manufacturers have to consider this fact when designing a tree cabling system. They have to build in a ageing reserve so that the stated load capacity of a tree cabling system can be guaranteed for the recommended service life.

In Germany the Tree Care Standard (ZTV Baumpflege 2006) specifies a minimum servic life of 8 years.

For a better understanding here an example:

A branch with a basic diameter up to 32 cm has to be secured. For this a tree cabling system with a load capacity of 2 tons have to be used. This load capacity has to be guaranted from the manufacturer for a span of service life of minimum 8 years.

To guarantee this the tree cabling system must have in new shape a load capacity that his over 2 tons, e.g. cobra 2 t has a load capacity (as system) of 3 tons when it is new.

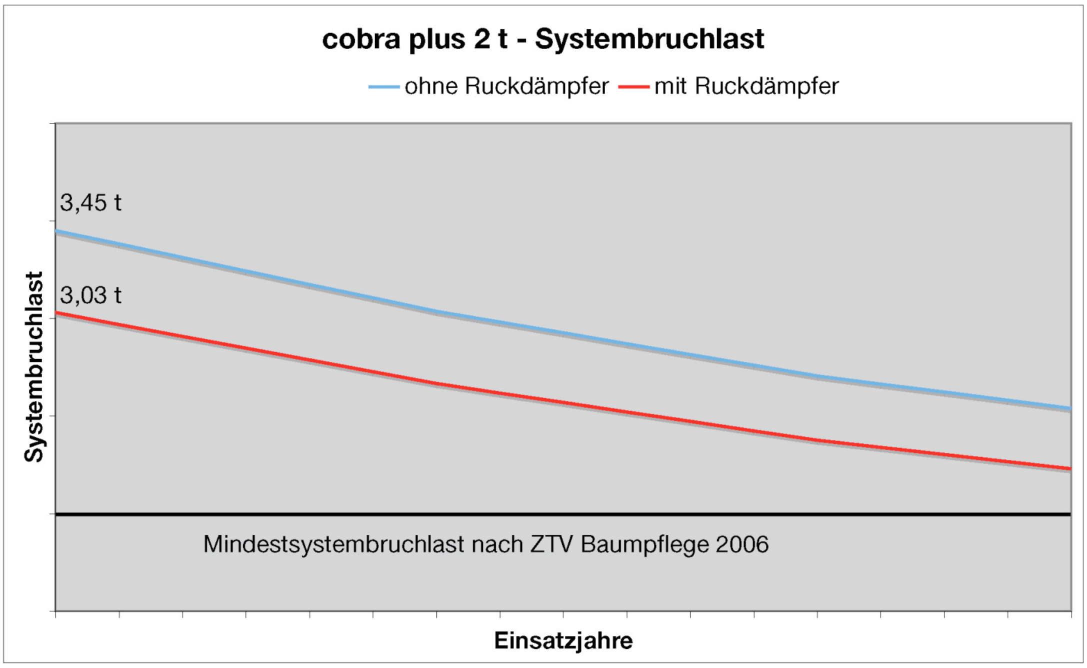


fig. 9 Load capacity of cobra plus 2 t during service life

4.1.4. The influence of the connection angle on stress effecting the cable and the load transmission to the counter bearing

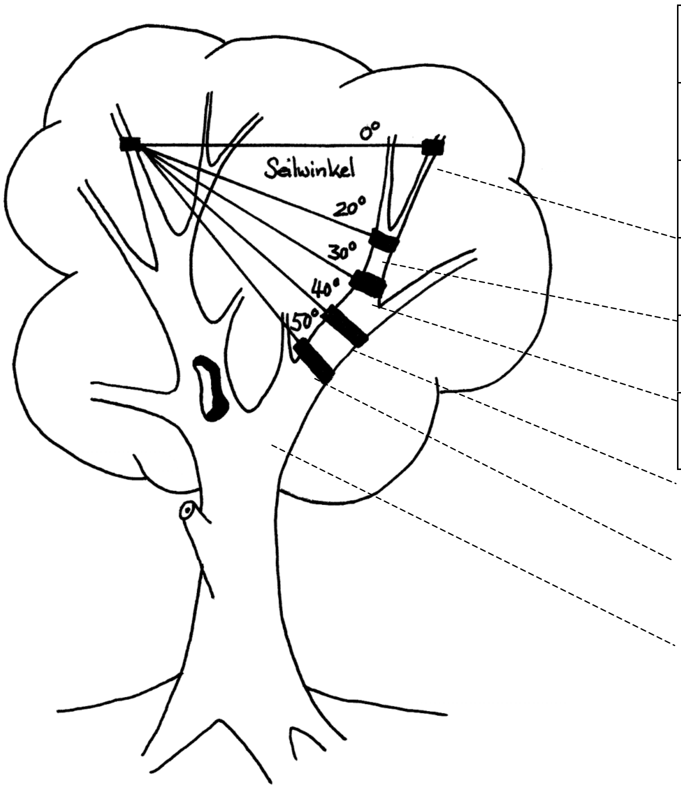
In storms a part of the windload is transfered from a weak tree part to a stronger counter bearing. The remaining load should stimulate the secondary growth of the weak branch. In turn the counter bearing must be strong enough to withstand the transfered additional load without getting a risk for its own. Normally the securing branch should have at least the same bearing capacity as the secured branch.

Notice: The bearing capacity of an anchor point can not be improved by installing a tree cabling with a higher load capacity!

But it exists a possibility to secure a weakend branch on a weaker counter bearing. Therefor the cabling has to leave the horizontal. This means the anchorpoint at the secured branch has to be above the anchorpoint of the securing branch. The variation of the connection angle has two effects.

- The leverage at the (weaker) securing branch gets shortend and thus the bending load on its crotch and the breaking risk are reduced.
- The load effecting the cable increases with increasing angle thus makes a higher dimensioning necessary.

Stress on cable	Stress on counter bearing



100 %	100 %
106 %	66 %
115 %	48 %
130 %	32 %
155 %	18 %
	0 %

fig. 10 Inclined cable reduces load affecting on the counter bearing

4.1.5. Elasticity

One of the advantages of synthetic cable compared with steel cable is their elasticity. Under load their fibres begin to elongate. But under low loads the elongation of synthetic cables is low too.

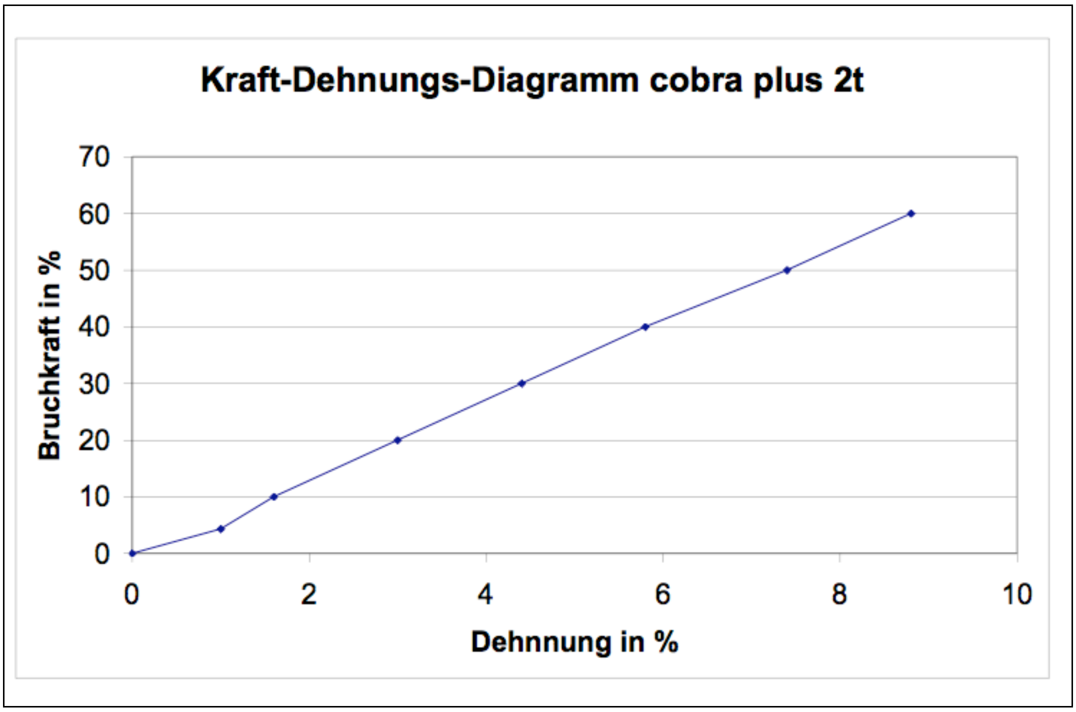


fig. 11 Stress-Strain-Curve cobra plus 2 t

Considering that synthetic cable must not be loaded with more than 30% - 50% of their load capacity during service the effective elaongation is about 5 – 8%. So the elasticity of synthetic cable is not optimal to allow branches to swing unhindered in gentle winds.

Some other tree cabling systems than cobra try to solve the problem by installing the cable with slack. But also this is not a good solution because the swing-rang without elongation depends on the slack of the cable. The shorter the cable the shorter is the swing-range without elongation. Of course to get enough swing-rang large slacks are needed.

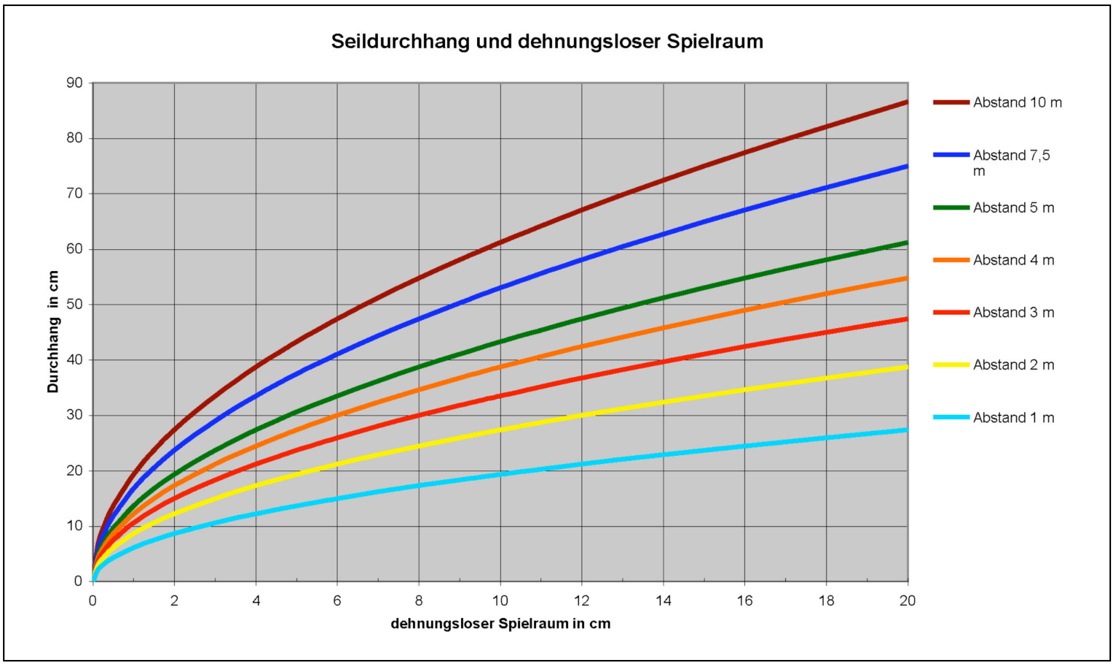


fig. 12 Slack and swing-range without elongation (DETTER)

Besides still heavy impact shocks may occure in storms when branches move in opposite directions and the cable gets thigtend and stopps the branches movement suddenly.

The diagramm (fig. 12) shows which slack allows which tensionfree swing range at different branch distances. For example a tree cabling (without shock-absorber) must have a slack of 60 cm at a distance of 5 m (green curve) to allow branches to swing 20 cm. A cobra tree cabling with shock-absorber provides the same swing range without slack. How this functions will be explained next.

4.2. The Shock-Absorber

The shock-absorber is the core element of the cobra tree cabling system. The reason it is so important is the fact that it solves the problem of impact shocks and improves the ability of cabled branches to swing unhindered.

fig. 13 cobra plus shock-absorber

The shock-absorber is the component that gives the cobra system more dynamic. It works in two different ways. How? That will be explaind next.

1. Additional swinging range thru extra stretch

When the shock-absorber is put into the cable it shortens it around 20 cm. Under load the shock-absorber is jamed inside the cable and gets strechted. This elongation effect begins to work in soft winds and low windloads – from 50 kg – and so it allows branches to swing nearly unhindered. This ability of the cobra system is called the 'Low Load Swing Range'. The following diagram shows the elongiation of cobra plus 2t with and without shock-absorber.

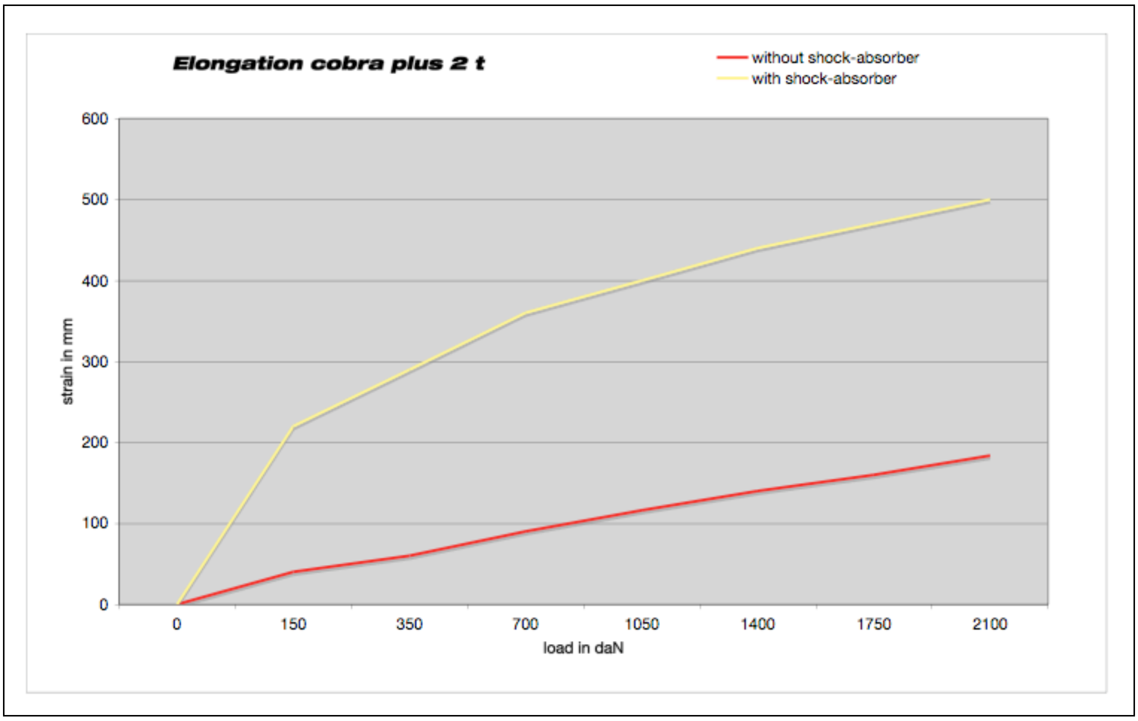


fig. 14 Elongation cobra plus 2 t with and without shock-absorber

This additional elongiation not only can be measured it also can be calculated, as the following example shows:

Calculation:

40 cm (Length of shock-absorber)

+ 20 cm (shortening of cable by the shock-absorber)

+ 10 cm (40 cm cable + 20 cm shortening of the cable x 0.17 % elongation of the cable)

= 70 cm

The cobra plus shock-absorber is 70 cm at the breaking moment thus it has been strechted 30 cm.

2. Cushoning of impact-shocks thru energy-absorbation

To view on this elongiation (that was explained above in a static way) under dynamic aspects shows the following.

If the cobra cable gets tightened and the shock-absorber gets streched then the shock-absorber saves kinetic energy that it releases by-and-by during the following oscillation process. Thus it chusions the impact shock and reduces the load affecting the branches.

If a system with shock-absorber is compared with a system without shock-absorber then the following gets visible.

a) The load increases slower in a tree cabling with shock-absorber than it does in a cabling without. This means a system with shock-absorber is more tree friendly.

b) The impact-shock is cushioned by a tree cabling with shock-absorber more clearly than by a system without. Thus the maximum load is reduced and a branch gets less stressed.

This dynamic behaviour can be simulated in drop impact tests. Hereby a certain mass x is thrown from a certain height h in a ‘hanging’ tree cabling system. The cabling system gets tightend, strechted and afterwards it oscillates until its movement dies. The following table is showing the maximum shock loads measured in drop impact tests made with cobra plus 2t – with and without shock-absorber.

Experimental set-up:

System: cobra plus 2 t (without and with shock-absorber); Mass: **55 and 100 kg**; Drop height **100 and 1000 mm**

Drop Height [mm]/ Mass [kg]	100/ 55	1000/ 100
Maximum impact-shock [kN]	4,45	17,32

fig. 15 cobra plus 2 t without shock-absorber: max. impact-shock

Drop Height [mm]/ Mass [kg]	100/ 55	1000/ 100
Maximum impact-shock [kN]	2,68	13,36

fig. 16 cobra plus 2 t with shock-absorber: max. impact-shock

Result:

The shock-absorber reduced the maximum impact-ahock by **23 % and 40 %.**

Those two abilities of the shock-absorber are making the cobra system to a superior dynamic tree cabling system.

4.3. The Expansion Insert

The expansion insert has two features as well. When put into the cable it expands the contact surface of that part of the cable that will lie on the branch. Thus on the one hand it will reduce the pressure affecting the bark and the cambium. On the other hand it will avoid the enlacement to grow in. The material of the cobra expansion insert is also blackend polypropylene.

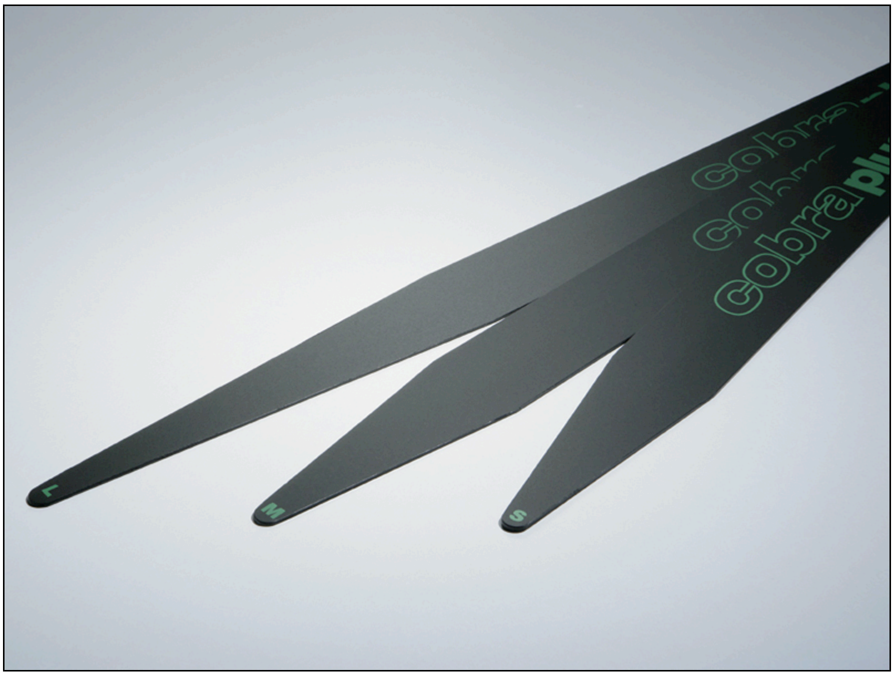


fig. 17 cobra plus expansion inserts. Size S, M, L

4.4. The Anti-Abrasion Hose

The anti-abrasion-hose is a textile hose woven from polypropylene fibres. It function is to protect the bark and the cambium as well as the cable against abrasion. Therefor it has to be pulled over that part of the cable that has contact with the branch and where the expansion insert is put in. Installed in that way the cable is moving inside of the anti-abrasion hose during the branches are swinging.

Not even to protect the tree from injuries is very important also it is very important to protect synthetic cable against abrasion. The reason is that synthetic cables react very damageable to abrasion and may lose a big amount of their load capacity in a short period of time if the fibres get rubed through.

Note: Always protect synthetic cable against abrasion. They should never rub anywhere in no way!

4.5. The Endcap

The cobra endcape is a heat shrink tube that is shrinked over the end of the cable to avoid that it frazzles. Also it is a smart methode to get a cable end that is easyly to splice.

Additional it is used as a mark for the age of the cable. Because every year has its own colour the year of installation can be checked easily.

cobra - Colours Of The End Cap							
green	yellow	red	blue	brown	violet	orange	grey
1993	1994	1995	1996	1997	1998	1999	2000
2001	2002	2003	2004	2005	2006	2007	2008
2009	2010	2011	2012	2013	2014	2015	2016

fig. 18 Colours of the cobra end cap

Also the installation year and the systems load capacity are printed on the endcap.

fig. 19 cobra endcaps

5. Installing A Tree Cabling System

Installation is the same for all cobra systems: cobra standard, 2t, 4t, 8t and mini cobra.

fig. 20 cobra - easy installation in six steps

1. INSTALL EXPANSION INSERT

Choose the appropriate length (length of expansion insert should be approximately the circumference of the branch). At a distance of the stem/branch circumference + 20 cm (8 inches) from the end of the cable, compress the cable and insert the expansion insert through a mesh into the cable.

2. MOUNT ANTI-ABRASION HOSE

Cut the anti-abrasion hose to length (minimum length = branch circumference) and pull it over the cable in the section of the expansion insert.

3. CREATE QUICK SPLICE

After winding the cable around the branch, feed the end of the rope through the inside of the cable (at a distance of approximately one-half the diameter of the branch). For mini, standard, 2t, 4t, the cable should be fed approx. 40 cm (16 inches) trough the inside of the cable. For the 8t, it should be fed approx. 50 cm (20 inches). Then, lead the cable out again.

4. FORM COMPENSATION LOOP

Form a loop and feedd the end of the cable again, this time about 10 cm (4 inches) for the mini, standard, 2t and 4t or about 15 cm (6 inches) for the 8t through the inside. then lead the end of the cable out again.

5. INSERT SHOCK-ABSORBER

Compress the cable at a convenient place and insert the shock-absorber.

6. INSTALL THE COUNTER BEARING

Repeat steps 1 through 4 at the counter bearing.

6. Use Of Cobra In Accordance With The German Tree Care Standard (ZTV Baumpflege 2006)

The German Tree Care Standard was first published by the FLL in 1987. It is a guideline that includes the knowledge and experience of practitioners – principals as well as contractors. Since 1987 these guidelines were revised repeatedly to refresh it to the latest state of knowledge. At last 2006.

In the German Tree Care Standard are definitions of terms, requirements for construction works and materials. Thus this standard serves as basis for tendering, contracting and invoicing of tree care works as well as for their monitoring and in this spirit it shows 'the generally accepted codes of practice'.

6.1. Principles

With the use of tree cabling systems, it is possible in many cases to avoid pruning and therefor maintain leaf volume, which is necessary for the development of wood cells. Choose the most suitable tree cabling system for supporting the structurally weak spot in the tree. The German Tree Care Standard distinguishes between dynamic breaking cabling, static breaking cabling and load-/support cabling.

Note:

Even with prunning and/or cabling, it is not possible to guarantee against tree breakage or crown failure.

6.2. Technical Features

cobra 2t, 4t and 8t meet the technical requirements for tree cabling systems as set forth in ZTV Baumpflege.

- cobra can be installed without damaging the tree.
- cobra is made of durable polypropylene monofilaments and, with a strength loss of less than 2% per year, has a service life of over 8 years.
- cobra can be individually adapted to the particular features and needs of a tree by using different component sizes.
- cobra's integrated shock-absorber and cable extension provide elasticity that is independent of length, which allows for additional play for movement in gentle breezes (the low-load swinging range).
- cobra's expension inserts and anti-abrasion hoses prevent damage to cable and tree from cutting in and abrasion.
- cobra's adjustable reserve loop enables the system to increase its length as the tree grows.
- because it is black, cobra is visually unobstusive.

6.3. Tree Cabling Types

The ZTV Baumpflege differentiates between two types of tree cabling:

- Breaking cabling
- Load-/ support cabling

Their function and how they work will be explained next.

6.3.1. Dynamic Breaking Cabling

For preventing breakage caused by oscillation-induced overstretching, install cobra 2t, 4t and 8t with a shock absorber as a dynamic breaking cabling system. That way, the oscillations of the crown are not impeded, yet load peaks from strong gusts are softly dampened. You should dimension the cable and shock absorber specifically for the particular tree's condition and situation. The higher the tensile strength of the rope and the lower the expandability of the rope and shock absorber, the more rigid the system is. As a result, the stronger the load peaks caused by shock-loading in case of strong swings.

6.3.2. Static Breaking Cabling

If damage is already present (i.e., formation of cracks), we recommend installing a cobra tree cabling system (cobra 4 t or 8 t) without a shock absorber or using the low-expansion cobra ultrastatic system, specifically developed for this purpose, as a static breaking cabling system. By immobilizing the critical spot, this type of cabling system prevents enlargement of the crack and helps prevent the branch from breaking off.

6.3.3. Load-/Support Cabling

If, for reasons of traffic or pedestrian safety, you want to prevent a broken branch from falling to the ground, install static load/support cabling system. We recommend a cobra tree cabling system without a shock absorber or the cobra ultrastatic. Either system should be installed as vertically as possible. That way, if the secured branch breaks, it will hang in the cable. The only acceleration will be from the cable extension, and, therefore, there will be little or no shock-loading. The rope and anchor point should be sufficiently strong to carry the weight of the branch.

6.4. Installation Rules According To ZTV Baumpflege

6.4.1. Dynamic Breaking Cabling

To optimally limit damage, install a dynamic cobra breaking cabling system at a point at least two-thirds the length of the branch to be secured. Under wind load, that point is near the load center of the crown. This installation point keeps the leverage forces as low as possible and helps ensure a low loading of the cable. You can achieve optimal dynamic behaviour of the system with a low tensile strength of the cable, which will protect the secured parts of the crown from overload and breakage. A lower installation requires higher dimensioning. Install the cobra connections during summer without tension or slack. In winter, install cobra with a slight amount slack so as to avoid permanent load during summer.

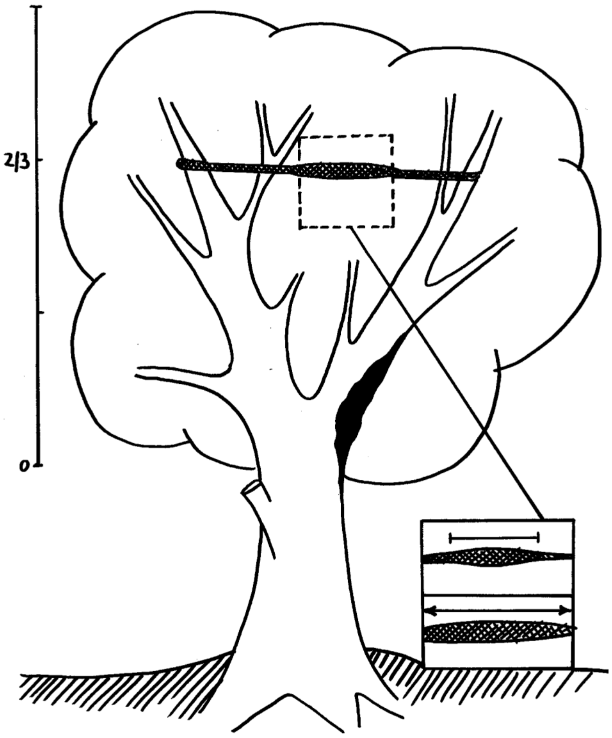


fig. 21 Installation height of a dynamic breaking cabling

The ZTV Baumpflege recommends the following minimum tensile strength for dynamic breaking cabling systems.

Basis Diameter Branch/ Stem	Minimum Tensil Strength Of A Dynamic Tree Cabling
up to 40 cm	2 tons
up to 60 cm	4 tons
up to 80 cm	8 tons

fig. 22 Minimum tensil strength of a dynamic breaking cabling

6.4.2. Static Breaking Cabling

Install a static cobra breaking cabling system at a point at least two-thirds the length of the part of the tree to be secured (branch or stem), for the same reasons that apply to a dynamic breaking/cabling system. In this type of tree cabling system, however, expandability is not desirable because a crack could be enlarged by movement. According to ZTV Baumpflege, you must therefore dimension a static tree cabling system at least two times higher than a dynamic tree cabling system. For example use a (static) system with a tensile strength of 4 tonnes instead of a (dynamic) system with 2 tonnes to secure a branch with a diameter of 38 cm.

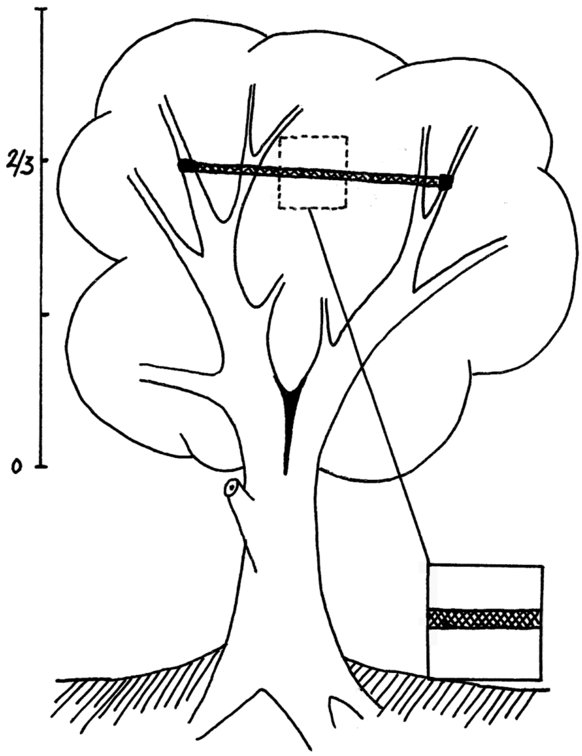


fig. 23 Installation height of a static breaking cabling

The ZTV Baumpflege recommends the following minimum tensile strength for static breaking cabling systems.

Basis Diameter Branch/ Stem	Minimum Tensil Strength Of A Dynamic Tree Cabling
up to 40 cm	4 tons
up to 60 cm	8 tons
up to 80 cm	16 tons

fig. 24 Minimum tensil strength of a static tree cabling

6.4.2.1 Connection Types

In conformence with ZTV Baumpflege cobra breaking cablings should be installed in accordance to the phsyological possibilities of the tree and in the form of one of the following connection types:

Single connection:

The simplest type to connect two branches with a tree cabling is the ‘single connection’. Often it is the only connection type that is possible because there are to few anchor points in a tree. IMPORTANT: The connected branches are not secured against sidewinds and thus they can swing sidewards until they break.

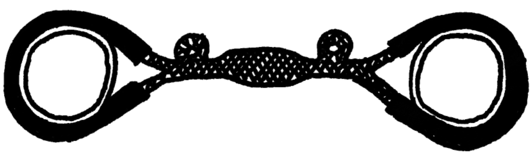


fig. 25 Single connection

Triangular connection:

This connection type connects three or more equipollent branches in form of a triangle. IMPORTANT: This connection type is optimum because it secures all winddirections. So in practice always try to install this type.

fig. 26 Triangular connection with three branches

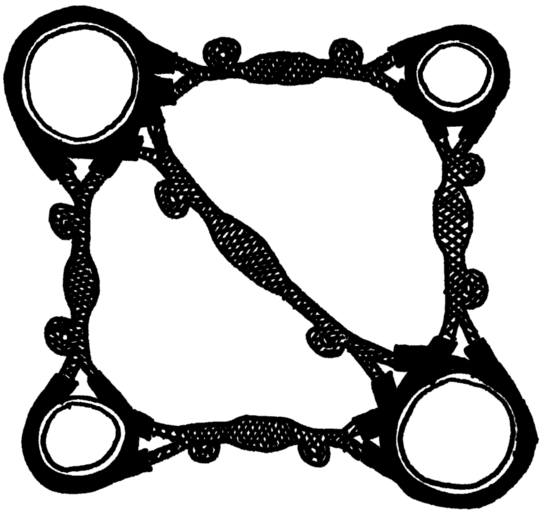


fig. 27 Triangular connection with four branches

Ring connection:

The ring connection has to be installed if just sidewise swinging has to be limited. This type is not very common in practice.

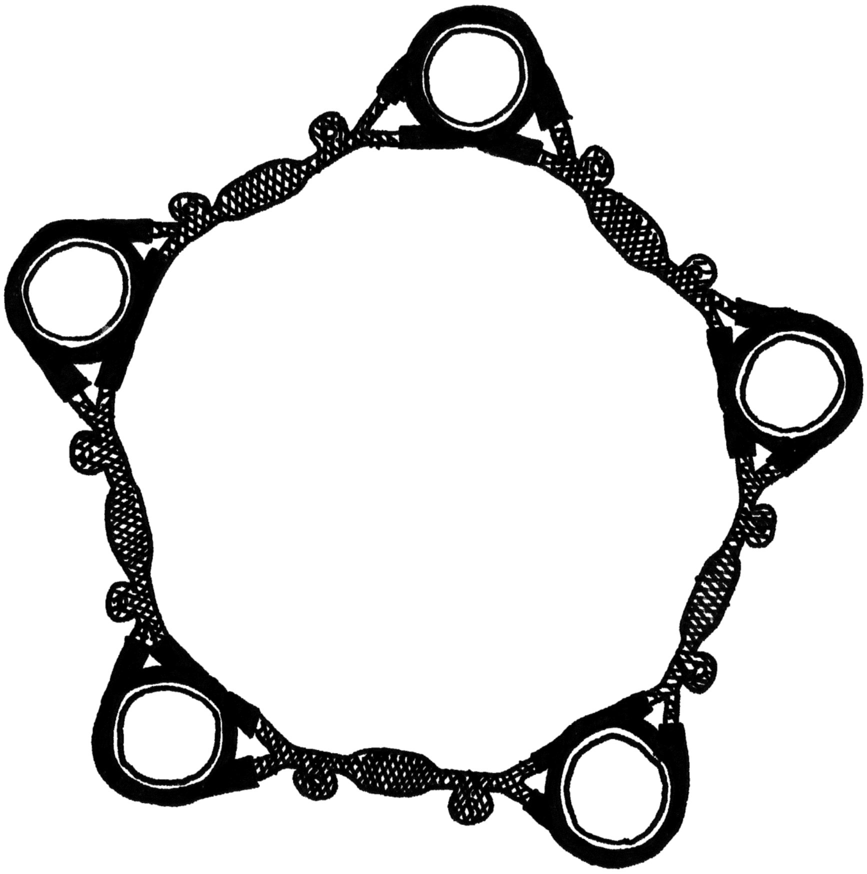


fig. 28 Ring connection with at least four branches

6.4.3. Load-/ Support cabling

For load-/support cabling systems, use a low-expansion rope and install it as vertically and tightly as possible in order to avoid shock-loading if the branch breaks, falls, and is caught by the rope. Shock-loading exposes the rope and the part of the crown that is secured to unnecessarily high stress, which could lead to breakage from overload. Therefore, the tensile strength of the cobra tree cabling system and the anchor point at the carrying part of the crown must be sufficient to carry the weight of the branch and exclude a sudden load. Tensile strength can be calculated with the tensile strength tables (shown below) in ZTV Baumpflege.

Basis Diameter	Minimum Tensil Strength Of

Branch/ Stem	A Dynamic Tree Cabling
up to 30 cm	2 tons
up to 40 cm	4 tons
up to 60 cm	8 tons
up to 80 cm	16 tons

fig. 29 Minimum tensil strength of a load-/support tree cabling

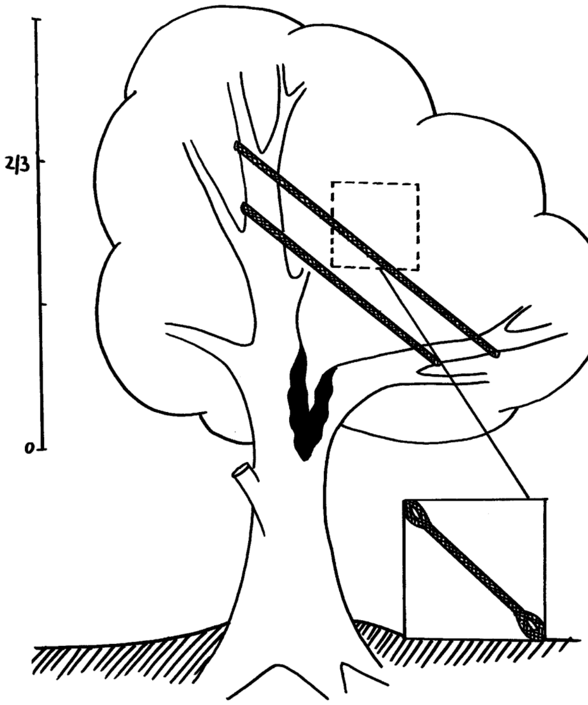


fig. 30 Installation of a load-/support cabling

7. Recording And Inspecting Tree Cablings

There have to be a log for every tree cabling to know when to exchange the cabling and to know when it must be inspected next. The inspection of the tree cabling has to be done in a certain interval. Then it has to be checked if erverything is still alright. This inspection is very important because if some failure happened and someone get harmed or something get damaged and it has to be determined who has to assume the liability. In this situation the recording of inspections helps to proof that one's duties were exerciesed.

7.1. The Record

Thus it is best to report the installation of a tree cabling system into a log. The following record should be made:

- What kind of tree cabling system was installed (Type and load capacity)?
- When was it installed?
- Where was it installed?
- Who installed it?
- Anything conspicuous noticed?
- When is the next monitoring interval or when was the last visit?

Often this work is done hand-in-hand with the regular tree inspection that is neseccary to identify trees that are a injured or dangerous for the public living. In Germany often a Geoinformation System (GIS) with a implemented tree cadastre is used.

Note:

"At least the date of installation hast to be recoerded." (German Tree Care Standard)

7.2. Inspection Interval

Because tree cabling systems are ageing and the surroundings within a tree are changing continually or the cable was overstressed by windloads they have to be controlled every 2 and 4 years. Perhaps it makes sence to vist it after heavy storms too. Also anything conspisuous noticed during the inspection should be reported in the log. The following has to be observed.

Visual inspection (with binocular from the ground) every 2 years:

- Installation height
- Slack span
- Tension
- Compensation loop
- Anti-abrasion hose
- Ingrowth and constriction
- chafe marks

Visual inspection (up in the tree) every 4 years:

- Filaments
- Meshes
- Imprint of meshes on shock absorber
- Deformed expansion inserts

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