Cable bracing, propping and related techniques

Cable, rod and belt bracing

What is it?

A method of linking the branches or the stem of a tree together with the aims of reducing the probability of tree or branch failure or stabilising a trunk or mechanical branch defect with signs of static failure (broken forks, rips etc.). The overall objective is to attempt to stop a branch failing and the tree falling apart or/and to minimise damage to people or property in case of a failure. It is often combined with light pruning.

Why/when to consider it

- When the amount of pruning required to stabilise the branch/tree would compromise the tree's viability.
- When there is a need to replace an old brace due to concerns that the branch/es will fall if it fails.
- In some countries it is most often used on feature trees or those with special values

Advantages of cable bracing

- Cable bracing can prevent one or more branches failing, helping to keep the tree intact. It can be used instead of heavy pruning that would compromise the tree's viability (e.g. when ripe wood or non-durable heartwood would be exposed by cutting or when the amount of foliage removed would be detrimental to overall tree health).
- It can be used as a temporary measure during a multi-stage pruning process; for example, cabling can prevent failure until the tree has been made more stable through several pruning operations.
- It can be used as a risk management tool, e.g. by minimising the risk of damage to people or property in the event of a failure.

Disadvantages of cable bracing

- It can be more demanding on the knowledge and skills of the arborist (e.g. selection of suitable equipment, correct location of cables, knowledge of the variety of bracing systems). Only specialists with sufficient expertise should install bracing in a biomechanically complex veteran tree.
- Needs regular inspection/maintenance.
- Can be expensive.
- Can be visually intrusive, although this can be minimised by conscious choice of material and construction.
- Can alter the force distribution in the tree or (unintentionally) alleviate strain at specific points (e.g. forks) and thus reduce the natural reactive growth of the tree.
- In the case of inappropriate installation, it can move the risk of failure to other parts of the tree (e.g. just above static cabling systems). Proper assessment before installing bracing systems is necessary.
- Can disturb or stop the natural aging process of the tree, which often includes a natural retrenchment process and branch breakage
- The whole tree may still fail, even if failure of part of the tree is prevented (although this could be unrelated to the cable bracing)

When considering installing a cable system, the following should be carried out:

- A review of all available products, and a careful examination of their properties, in order to select the best one for the situation.
- **Ensure there is sufficient weight bearing capacity** according to the literature (ZTV Baumpflege, 2006) or by considering applied load and branch mass.
- **Selection of appropriate cable locations and geometry of installation**. The impact of installed systems to force redistribution needs to be considered even **if** there is limited knowledge about the dynamic (frequency, damping) and static (stress/strain distribution) mechanical response to wind load.

The installation of the cabling system is more demanding on the technical and biological knowledge of the arborist due to a variety of possible approaches and cabling systems. It also requires an understanding of the tree's mechanical response to wind loading. Therefore, it is recommended that more in-depth knowledge is gained, or specialised training received, before recommending or installing cabling systems.

Following text is only a brief overview of the topic, for more detail see the bibliography.

Cabling systems

Cabling systems are divided into two main categories: dynamic and static. They differ in their aims, material and system of installation. Both have advantages and disadvantages, and the choice depends on the condition and mechanical structure of the tree.

Table 1 The basic principles and differences between static and dynamic cabling systems.

	Properties	Types	Aims	Advantages	Disadvantages
Static systems[1]	• Systems with components made of rigid materials (with low elasticity – up to 2%). • Installed under tension.	• Static ropes • Fixed rods • Steel ropes	• To stabilise the trunk, or branch defect **with signs of failure** (broken forks, rips etc.). • To fix the branches/parts of the tree in a very rigid way.	• Provides very strong, secure brace.	• Expensive and demanding on installation. • Regular revision is needed. • Can be intrusive (depends on the system, see Table 3). • Can change the strain distribution

[1] The definitions of dynamic and static systems can vary between countries. The division and definitions in this fact sheet follow the basic aims of the systems: a) static systems, which fix the defect tightly and must be installed under tension b) more preventive dynamic systems which should be installed allowing the tree some degree of movement. For different divisions and advanced use of dynamic ropes see the manufacturer's websites or see Detter, Wassenaer (2006).

					and reduce the natural reactive growth (tree self-optimisation). • Can increase overall tree stiffness and reduce the tree ability to deal with dynamic loading [2].
Dynamic systems[1]	• Systems with components from materials with high elasticity (5-26%). • Installed with allowance for future growth and with slight slack in the rope.	There is range of cabling systems from different manufacturers. It is important to check the manufacturer's conditions of use and recommendations (e.g. durability of the system, carrying capacity, elasticity, revision interval, etc.). Three main kinds of rope material: • Polyester • Polypropylene • Polyamide	To reduce the probability of tree or branch failure by: • Eliminating the stress peaks by damping energy during rope elongation. • Installation of cabling system as a preventive measure – to catch the branch in the case of failure.	• Flexible, allows the branches to move and conduct reactive growth. • Can be adjusted as the tree changes over time. • If appropriately installed (correct tension/protective sleeve etc.), minimal damage to the tree is to be expected.	• More frequent re-installations and regular revisions are needed (according to manufacturer's instructions) so increasing associated costs. • Can be damaged (e.g. by friction or squirrels).

[2] There are studies looking at the tree's dynamic response to wind load and the importance of branch movements. The branches help to dissipate energy flowing from acting wind force through damping. The static systems eliminate the natural movements and increase the stiffness of the whole system (tree). **This should be considered in the case of a significant biomechanical defect at the tree base.** However nowadays there are some studies showing that the difference between trees in leaf and those that are bare is more significant than the effect of the treatment (Kane 2018; Reiland et al. 2015).

Static cabling systems

Static cabling systems differ primarily in the method used for fixing the rope to the branch. The other difference lies in the rope material used to connect the branches (Table 3).

Table 3. The main types of static cabling systems.

Method	Technique	Advantages	Disadvantages	Notes
Synthetic rope	Synthetic static/ultrastatic rope is connected to a synthetic belt, which is tied around the branch or stem[3].	• Easy installation. • If appropriately installed (correct tension/protective tubing/…), minimal damage to the tree at the time of installation	• The rope should be installed under tension, which causes a tight connection between the belt and branch in the place of installation. There is a high probability that the belt will quickly be subsumed by the tree/branch and thus damage. • The rope is sensitive to friction and can be damaged.	
Wire wrapped around the branch/stem.	Metal wire is used for connecting the branches and is wrapped directly around the branch.		The high friction between the wire and tree causes damage in a vigorous growing branch. Wires cut into the tree and cause unnecessary damage.	Should not be used.
Wire rope and slats wrapped around the branch/stem.	Metal wire which is connecting branches is wrapped around the slats. The slats are fixed to the branches.	• If appropriately installed (correct tension/protective tubing/…), minimal damage to the tree. • Can be used on partially decayed branches or stems where residual wall thickness is sufficient.	• Expensive and demanding on installation. • If not installed and controlled properly, slats can cause damage to the branch, or can fall out. • In the case of extreme wind, the movement of branches can release the tension on the system and the connection between rope and slats can be damaged.	It is recommended in the cases where branch decay is expected at the location of installation.
Wire drilled through the stem or	A hole is drilled through the branch/stem through which wire is installed, secured and ensured	• Can also be used on soft-wooded tree species, in contrast to screw eyes.	• Damages ripewood/heartwood. • Creates a larger wound than a screw eye.	Cannot be installed where there are signs of fungal decay.

[3] According to the German standards dynamic ropes can be used in a static system. The recommendation is to use rope of a higher carrying capacity without a shock absorber. This approach is not recommended in other countries. If this kind of installation is being considered, the manufacturers instruction should be followed carefully.

connected to rod/eye bolts.	by a block on the opposite side. Or wire is attached to a rod or bolt that extends through a branch or stem.	• Easier installation than the wire with slats. • If there is no sign of decay and the tree has high vitality, the wire/rod can prevent damage to the branch. No reinstallation needed.	• Can be more demanding on skills and experience when installed on large diameter branches or stems due to the requirement to drill a straight hole all the way through.	The wire passes through the whole branch potentially causing large scale damage.
Wire connected to screw eyes (short screws into the tree).	Wire attached to a short screw that relies on gripping part of the branch or stem cross-section.	• Easier to install than an eyebolt. • Potentially causes less damage than a rod/eye bolt, as it is installed in the sapwood only.	• Not suitable for use on soft-wooded tree species (e.g. willow and poplar) as pins can be pulled out. • Should not be used on large diameter branches or stems because of their lack of strength.	Should not be used on partially decayed branches or stems.
Fixed rod	Steel rod put through the tree at the base of the branches or through a fork. Used when the branches are too close to each other, or tree has a split in the trunk and is in danger of falling apart.	• Can be used for branches which are very close each other. • If there is no sign of decay, the tree has high vitality, and the wire/rod is installed through a branch, overgrowth by the tree over the rod may not be a problem and is easier to manage than ropes around the branches which will need loosening as the tree grows. • No reinstallation needed. • Provides a very strong, secure brace.	• Damages ripewood/heartwood. • Strongly reduces the flexibility of the tree close to the braced area of damage. Makes it very unlikely the tree can produce reactive growth. • Once installed, it should not be modified or adjusted. If this may be necessary, it has to be considered at the time of installation.	Not suitable when the braced part of the tree contains decayed wood due to the possibility that the rod will get pulled out if decay extends to the installation point.

General comments on static systems

There is not such a wide variety of static cabling systems commercially available as in the case of dynamic systems. The kind of bracing systems mentioned above can vary in the way components are used and in the method of installation. It is strongly recommended to use the compact systems which are provided by the manufacturers/salesman or to discuss the installation with a professional in the field of tree biomechanics. The following rules are just a general overview, mainly considering the tree requirements.

- All components which are carrying the load need to have sufficient load bearing capacity (Tab. 4), to last for the whole life of the tree.
- It is recommended that tree owners are provided with a protocol in which all the materials and components used are listed.
- Wires (ropes) in the crown must not touch each other.
- The carrying wire (rope) must not touch the tree, or any other object, unless it is protected in some way, e.g. with a sheath or connected to a belt (with the exception of wires going through the stem).
- For systems which are drilled through the stem:

    - The bored holes should not go through the branch collar.
    - It is recommended to keep a vertical distance of at least 50cm between bored holes on one branch to prevent a crack forming between them.
- For a system with slats:
    - The system must be installed under tension to ensure a fixed position for the slats (no loosening in the wind).
    - It is recommended to keep at least 2cm between the rope and branch (i.e. using slats at least 2cm deep).
    - It is recommended to use slats from hardwood species and with sufficient width and length to prevent ingrowth into branch.
    - It is recommended to have spaces between the slats equivalent to their width.
    - The shape of slats should eliminate the possibility of failure.
    - It is recommended to fix at least those slats which are at not under tension, i.e. the inner ones.

Location and dimension of static systems

- Static systems are installed in the lower part of the crown; the lower half taken from the location of the defect.
- Careful consideration should be given to the branch length, rope angle, mass of cabled branches, height of the installation and the wind force.
- For further guidance see ZTV Baumpflege (2006) which is the German standard

Dynamic cabling systems

- **General Rules –** During the installation of cabling systems the manufacturer's instructions must be followed. It is recommended to use all parts of the cabling system from the same manufacturer. The ropes must be installed with a slight slack in the crown. **The ropes should not be tight during the whole time they are installed in the crown.** For this reason, there must be sufficient reserve of rope behind the interlock or in the incremental loop.
- The ropes carrying the load must not be in direct contact with branches or other objects. There must be a cover around the rope if this cannot be avoided.
- The distance between branch and interlock (or connection between the part going around branch and rope) should be 0.5 of the branch diameter at the installation location. The angle between ropes leading to the interlock (or sleeve) must be less than 60° (Fig. 1).
- The eye of interlock has to be covered (no friction between the rope and branch is allowed).
- The fixing of the interlock must be according to the manufacturer's instructions or national standards.

Location and dimension of dynamic systems

- Dynamic systems should be installed only in the upper part of the crown; in the top half taken from the location of the defect.
- It is possible to use more than one cabling system in a tree or a combination of dynamic and static systems if needed with respect to the defect and crown size.
- The length of rope should ensure that in the case of branch failure, there will be no damage to the target.
- Careful consideration must be given to the branch length, rope angle, mass of branches to be cabled, height of installation and the wind force.
- For further guidance on calculating the breaking strength for dynamic cabling systems see ZTV Baumpflege (2006) which is the German standard and Wessolly (2007).

Geometry of cabling in general

Note that often more than two branches on the tree are braced together and this may especially be the case with veteran trees. Options for bracing include:

a) **Direct connection** – connecting two branches directly, and only dealing with the loading in the direction of ropes.
b) **Triangular configuration** – this system can offer support for the secured part of the crown in more than one direction. When branches and stems are connected, a system of one or more triangles is installed to form a network that reduces swaying in several directions. This installation method also serves to dissipate wind energy to several parts of the crown through the cables.
c) **Ring-shaped configuration** – this system can deal only with lateral swaying forces. This type of combination offers good opportunities to avoid excessive pruning, especially in secondary crowns and when securing regrowth that occurs after topping.

In the case of unequal installation (i.e. when one branch is smaller and the cable must be set at a higher angle) it is necessary to ensure **that the carrying branch (anchorage point) has sufficient carrying capacity** (e.g. it has no signs of decay, and that smaller branches are connected to stronger ones etc.).

In more complicated cases, there is always the possibility to use a combination of cabling system at several levels. In such cases, it is important to consider the influence of changes in force distribution and natural tree optimisation.

Revision and replacement of cabling systems

Every cabling system has to be checked regularly. The manufacturers define the interval between checks. Is recommended to provide the owner with a schedule in relation to each check and for any additional work carried out.
Cabling systems have to be replaced:

- after reaching their maximum life span as defined by the manufacturer,
- in case of damage,
- in case the tree condition has changed significantly,
- after failure of a significant part of the crown,
- after overload of the cabling system (some models include a warning system, e.g. a coloured thread with a lower breaking strength).

The manufactures define the durability of systems or their components.

In the case of reinstallation (replacement), the same approach should be taken as with a new installation, including tree assessment.
Before the removal of the old cabling system, the tree (defect) must be appropriately dealt with.
If a cabling system is removed that has become ingrowth into the tree, ensure that the tree cannot be damage by removing these parts.

If a reinstallation is recommended it should be carried out in the following order:

a) dynamic system
   - pruning if necessary
   - remove the old system

    - installation of the new one
b) dynamic system under tension
    - pruning if necessary
    - install backup system
    - remove the old one
    - slow release of backup system
    - installation of the new one

c) dynamic system that must be changed to static
    - pruning if necessary
    - install backup system
    - installation of static system
    - remove the old one
    - release of backup system
d) static system
    - pruning if necessary
    - install backup system
    - installation of static system, matching the old system so mechanical force flows in the tree change as little as possible
    - remove the old one
    - release of backup system

It is not recommended to add additional braces without removing the old ones. This can lead to trees festooned in cables and rods which may detract from their appearance. Installing static bracing also changes the way the tree deals with the forces it is exposed to; this makes future management decisions on structural integrity more difficult.

Free information about installed cabling systems, their durability and controls can be found at www.checktrees.com.

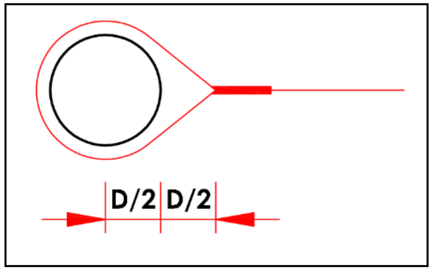

Fig. 1 Recommended distance between the interlock and branch

Fig. 2 Dynamic cabling system installed in the secondary crown

Fig. 3 Cabling system installed under tension

Fig. 4 Installation of static cabling system with slats. (Photo: Antonin Ambros, Orez Stromu).

Fig. 5 Installation of bracing system with two levels:

i) static system in lower part of crown to eliminate the stress around a defect in the fork,

ii) dynamic system in upper part to eliminate the branch deflection to reduce stress at the point of the static bracing below. This special kind of treatment has been carried out because of the tree size, significance of defect (fork wit decay and split) and target (cemetery). (Photo: Antonin Ambros, Orez Stromu).

Compression belts

In addition, some old fragile trees have had (usually) metal belts installed right around the hollow trunk. Sometimes this has been done to stop important habitat such as brown rot from falling out of the tree. This system also has advantages and disadvantages:

Method	Technique	Advantages	Disadvantages
Compression belts	Can be a bespoke metal belt that is bolted together, a ratchet strap, similar to those used by lorry drivers, or a steel cable running through eye bolts.	• Can help keep the trunk together and prevent shell buckling. • Ratchet straps are cheap, load tested and can be adjusted once on the tree.	• Detracts from the aesthetics at a very visible location (typically around eye height). • Requires inspection and adjustment. • Bespoke metal belts are expensive and cannot be adjusted. • In case of metal belts or ratchet straps, the physiological function of the tree is impacted because the bands limit growth. In dealing with a mechanical problem this may introduce others.

In summary

- Bracing may be worthwhile in some circumstances.
- Make sure that the work is carried out by a person/company with experience and a track record of carrying out this type of work and ask them to explain the positives and negatives of the system they are proposing. It is worthwhile to keep a written record of their recommendations for future reference.
- Bracing may give some confidence that the tree has been made less likely to fail.
- It can be expensive to install and will need ongoing maintenance and checks.
- Bracing can prevent the tree from using its natural strategies to mitigate for the problems and in circumstances where the tree is not in danger failing, or of hitting any target, then this may not be the best option.
- Look at examples on www.checktrees.com.

Fig. 6 & 7 Examples of compression belts.
Left: Two belts on the same tree.
Right: belt holding in some decaying wood

Guy ropes/Tethering

Tethering is similar to bracing, but the tree is attached to another tree, or the ground, in an attempt to prevent it from falling in a particular direction. The most common use is to prevent a feature tree or tree with high nature conservation values from falling where it might cause damage to a target (such as road or car park). See bracing for further details on the advantages and disadvantages of the material used and method of attachment to the tree.

Tethering is a special kind of cabling. When installing an individual approach has to be applied. It is appropriate to consider:

- The effect of side load
- The carrying capacity of the system
- The condition of the tree in the region of will be the anchor point; an assessment of the strength of the anchor point is needed.

Fig. 8 Tree tethered to prevent it from falling into the road

Propping

What is it?

Method of holding the tree or a branch up to stop it from falling.

Why/when to consider it?

When a branch is in danger of falling and breaking the tree apart
When the tree is in danger of falling over

Fig. 9 Simple tripod prop

Fig. 11 *Wooden props (left) later supplemented by metal props (right) which have plates*

Fig. 12 *Prop to prevent branch breaking if it fails (right)*

Fig. 10 Multiple props on branches

What type of prop to consider:

Props can be wooden or metal, simple or complex, fixed to the tree or allowing the tree to move. The following are a few things to consider when deciding what type of prop to use:

Material

- Wooden props offer the greatest flexibility as they can be constructed and adjusted on site. Will wooden props last long enough/be easy to replace once they decay? You may be able to source the material for wooden props on site, helping to reduce costs. It may be expensive to buy long sections of wood to support high branches.
- Metal props will last longer than wooden props. However, their fabrication can be specialist and expensive. Unless the constructed in a way to allow for adjustment (e.g. with a moveable head) they may be difficult to install.
- Could the ground be raised to the branch to avoid it being broken when it fell? Or, if the branch fell would it reach the ground without damaging the tree? Can the breakage and lowering of the branch be managed, so that the branch can touch ground without catastrophic breakage and dieback?

Fixing

- Does the prop need to be fixed to the ground?
- Does the prop need to be fixed to the tree? (if it is not fixed the tree may have a chance of putting on adaptive growth but if it is very vulnerable to falling it may need to be fixed)

Placement

- Could the prop be arranged so that the branch is free, but the prop catches it if it falls, before it does any damage?
- Where is the best place to put a prop for it to work without compromising the tree's natural movement?
- Is the tree growing/moving in a way that the prop will need to be changed or adapted in the near future? If so, using a system that can be, for example, raised or lowered may be considered.

Effects on the tree

- If the prop is in contact with the tree, what effect will this have on the tree? Should this be shaped to spread the load or some form of cushioning used?
- Is the prop likely to increase the chance of failure in the future or cause the tree to fail elsewhere?
- What about the future, how long is the lifespan of the prop? Where would a new prop be placed if this one becomes defunct?

One major consideration is cost. While a simple prop can be cheap to make and install and require minimal checking, other trees may have very complex requirements and/or need regular modification by specialists.

Before the installation **the carrying capacity of the system** and **effect of side load** should be considered individually.

Public perception of these methods

All these intrusive methods can detract from the appearance of the tree and make it appear less 'natural'.
Conversely, showing that time and money has been spent on the tree may make it appear more valued and special.
There are cultural differences between countries and regions in terms of how acceptable bracing is and how it is perceived, both by the public and by arboricultural professionals.

It is important always to do what is considered best for the long-term survival of the tree rather than chose a method because of public pressure.

Final note:

This fact sheet should not be viewed as a definitive guide to bracing and cabling. Anyone proposing to use such techniques should ensure that they consult with those that have direct experience of the techniques.

Further information & references:

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