barrell
TREE CONSULTANCY

Trees and structural damage

Supplementary Information Note to accompany the BTC 2011 RICS presentation series

BTC/51/2011

Trees and structural damage

The underlying risk of structural damage from trees is low

As far as the popular press is concerned, it is still very much a 'home-truth' that the only good news is bad news, and trees are no exception to that rule. There is no real drive to report on the multitude of tree benefits, but there is certainly plenty of journalistic commotion around events that can be portrayed as threatening, irrespective of the risk involved. Simplistically, the risk of being killed by a falling branch or tree in the UK is about 1:10,000,000, compared to the risk of being killed in traffic accident of about 1:18,000. Although 500 times less likely, the tree event will get the highest profile and the myths about the risks from trees are perpetuated.

There is a similar level of misinformation about the potential for trees to damage property and specifically residential homes because that is where the temptation for sensationalisation is greatest. In most cases, the press scare-mongering about the threat to our homes is both exaggerated and unwarranted. For every instance of damage from trees, there are thousands of other similar juxtapositions where there are no conflicts. However, although the risks are obviously low, trees can harm structures and understanding the damage mechanisms is essential for property managers to correctly diagnose the cause of structural problems and manage the solutions in a balanced and rational manner.

Tree damage mechanisms

Tree roots can influence and cause damage to structures in the following ways:

Directly through root growth: As tree roots grow in size, they will exert forces on anything they touch, which can cause damage if they come into direct physical contact with structures. However, there is a biological limit to how much pressure can be exerted through cell division and expansion, which means that only light structures such as hard surfacing, drains, small walls and small buildings can be damaged by this mechanism. Roots do not have the capacity to lift heavier structures such as substantial garages or houses, and will distort or stop growing before they can exert sufficient pressure to cause damage. It is worth remembering that the forces required to displace even substantial structures sideways can be much less than to lift the same structure vertically, so roots have a surprising potential to cause lateral displace damage. Damage to susceptible structures can occur on any type of soil and at any distance from the trunk that roots can reach. Damage caused by this mechanism will typically be progressive, with the degree of distortion gradually increasing over time (Figure 1).

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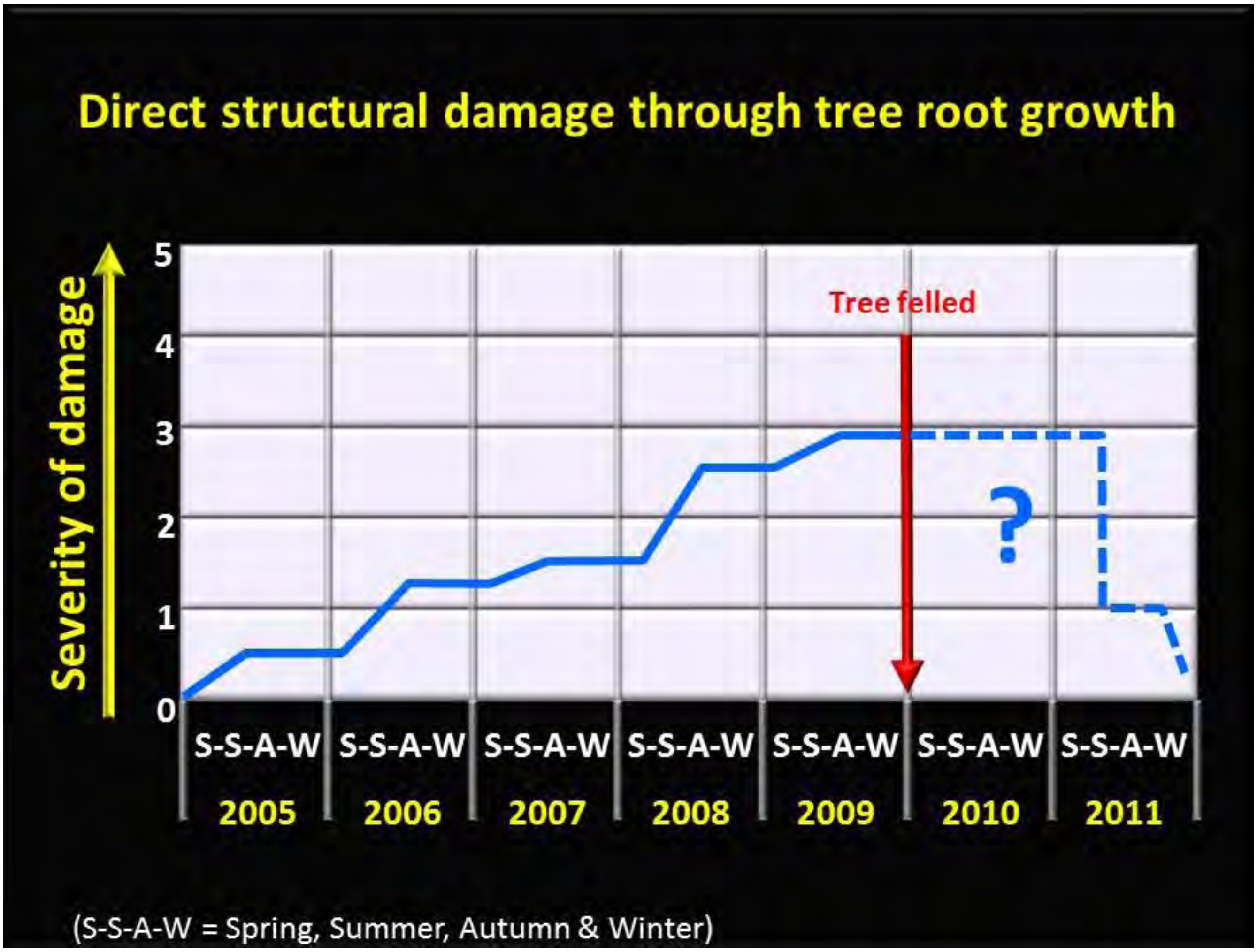


Figure 1: Structural damage from root growth can only occur when the roots are increasing is size, i.e. in the spring and summer, with no further significant distortion when they are dormant in the autumn and winter. The extent of damage can vary from year to year, depending on how much root growth there is in any year. The damage is progressive, i.e. it gets gradually more severe, and there is not normally any recovery while the root remains alive. When a tree is felled, the severity of the damage will not increase, but as the root decays over a number of years, there could be rapid collapse as the support weakens and eventually disappears.

Trees and structural damage

Photo 2: Root growth from this young Monterey pine has severely disrupted car park surfacing (Ferndown, Dorset)

Photo 3: Pavements and sidewalks all over the world are susceptible to lifting from root growth (New York)

Photo 4: Root and trunk growth will deform around robust structures if the forces required to move them are too great (Geneva)

Photo 5: Tree trunks grow outwards from their starting position as a sapling, and will often distort around firmly-fixed objects rather than push them aside (UK)

Trees and structural damage

Directly through transmission of trunk movements through large roots: Where large structural roots touch a structure, it is possible for trunk movements to be directly transmitted through those roots and to cause damage. This is unusual and can only occur with large trees, typically greater than 50cm trunk diameter and tall enough to sway significantly in the wind. As structural roots usually rapidly decrease in size beyond the trunk, this damage mechanism is only possible if the tree is very close to the structure, i.e. within 1–2m.

Photo 6: The potential for damage to this light structure from both root growth and transmission of trunk movements is obvious (UK)

Directly through rootball displacement: Trees can blow over in severe storms, displacing a significant rootball, which includes larger roots and much of the soil volume they encompass. If this rootball is in contact with a structure, its displacement can cause damage. This damage mechanism is unusual and can only occur where large trees are very close to structures.

Photo 7: This 25m Monterey pine blew down in the 1990 storms, bringing up the pavement and services with its massive root ball (Ferndown, Dorset)

Indirectly through shrinking of supporting soil: Clay soil changes in volume as its moisture content changes and structural damage caused by this process is commonly referred to as tree-related subsidence. As water drains through gravity or naturally evaporates or is removed by an external drying influence, clay shrinks in all directions, causing cracks at the surface that extend down into the soil (Photo 8). It is generally accepted that drying caused by the climate, i.e. the wind and sun, mainly affects the upper horizon of the soil profile, rarely extending beyond 0.5m depth. However, roots from low-height surface vegetation, including grass and shrubs, have the capacity to dry the soil down to depths of at least 1m.

Photo 8: Clay soil shrinkage is obvious on the surface, but this cracking occurs in three dimensions and extends down into the soil profile. Tree roots are able to quickly (over a period of days) grow into these developing cracks and begin extracting more water, propagating the cracking deeper and deeper. The young roots can survive the winter as the soil re-wets and the cracks close, ready to begin extracting moisture in the spring, progressively increasing the zone of cracking and extending further into the soil profile.

Some tree species have the capacity to extend roots deeply into clay soils, with the ability to rapidly extract water from depths of 3–4m, and sometimes deeper in the most extreme cases. This influence can extend as far from the tree as the roots can spread. A tree's capacity to exert this influence is affected by its ability to grow roots at depth and will vary with species. Oak, elm, cypresses, poplars and willows are noted as the most common species involved in damage by this mechanism. If a structure is relying on this soil for support, then these moisture related movements can reduce that support and cause damage if the building is not designed to cope with these fluctuating conditions. Typically, the amount of drying, and thus the amount of soil shrinkage, is greatest closest to the tree, and it is this differential shrinkage (support for the structure) that is the main problem. For damage to occur, there has to be a shrinkable clay soil, tree roots have to be present beneath the structure, there has to be restricted water input into the soil and the structure has to be unable to cope with the varying support from the soil. Damage caused by this mechanism will typically be cyclical, with the degree of distortion fluctuating between summer and winter as the moisture content of the soil varies (Figure 9).

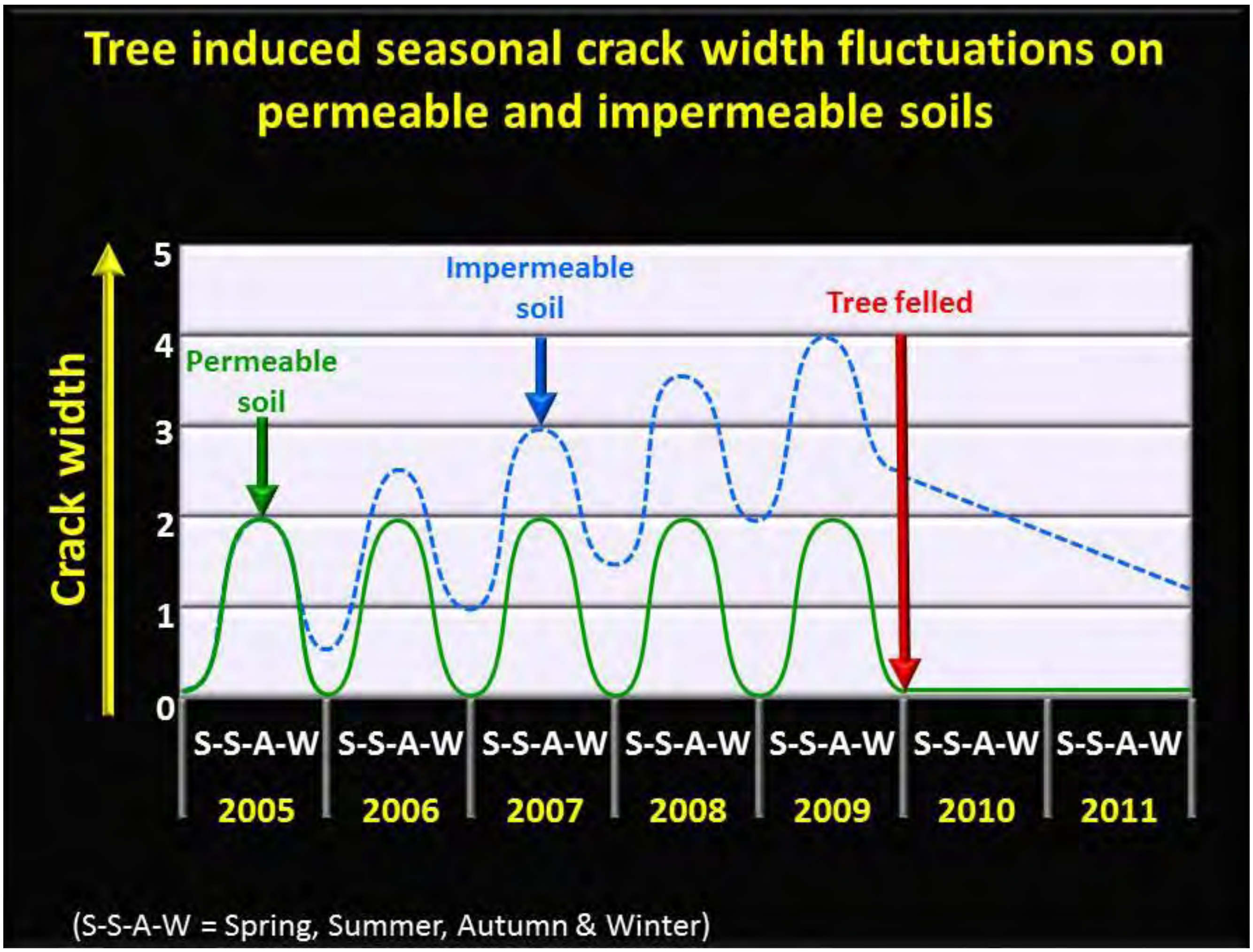


Figure 9: Damage caused by tree-related subsidence is typically expressed as cracks in susceptible structures, and the width of those cracks fluctuates with the season, i.e. roots are active in spring and summer, becoming dormant in autumn and winter, which is reflected in crack width.

Structures affected by tree-related subsidence typically show signs of damage through cracks at the weakest points, often from the corners of windows or doors, that step diagonally through the courses of brickwork (Photo 10). A critical factor in the development of damage is the permeability of the soil. In permeable soils, where water can move relatively freely, any moisture deficits that build up in the summer during peak root drying will disappear over the winter as rainfall water permeates into the soil, bringing it back to field capacity. The green solid line in Figure 9 illustrates this, with the cracks opening most in spring and summer, and fully closing during autumn and winter. However, if the soil is highly impermeable, such as London clay, then the winter rains may not be able to fully re-wet the soil. Over a period of years, this can result in a persistent soil moisture deficit developing with the structural movement getting progressively worse; the cracks still show the seasonal fluctuations, but each year they do not quite recover to the previous width, and over a number of years, they become wider and wider. The blue dashed line in Figure 9 illustrates this, with the cracks not fully closing each year to the previous width, and progressively increasing in width over a period of years.

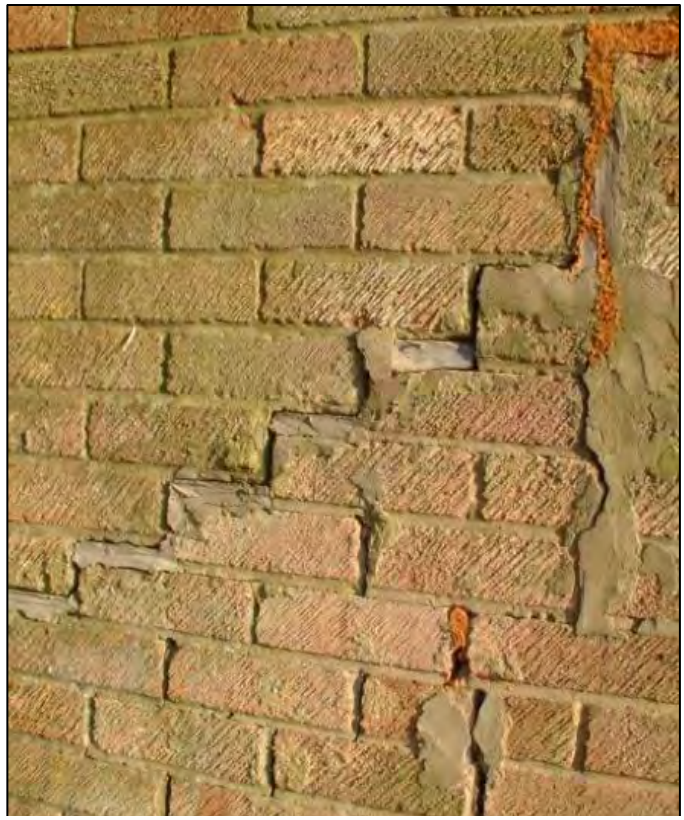
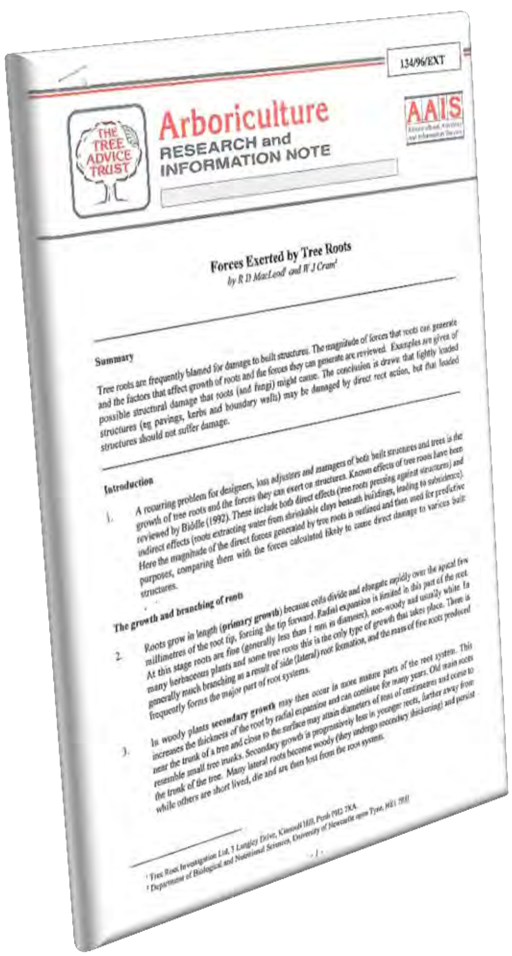


Photo 10: Typical cracking patterns caused by tree related subsidence

Notes on heave and recovery: For the purposes of this document, heave is defined as the uplifting of a structure above the level it was originally built at through the re-wetting of clay that was desiccated <u>at the time of construction</u>. For heave to occur, a structure has to be founded in a clay soil that has a well-developed persistent soil moisture deficit, i.e. it is extremely dry, and therefore shrunk, with the capacity to significantly swell when it re-wets. Persistent soil moisture deficits are more likely to develop on impermeable soils, where the movement of water through the soil profile is very slow and re-wetting takes a long time, often many years. Heave can only happen if the structure was built after the tree had the capacity to create a persistent moisture deficit, i.e. the building is younger than the tree. It takes a number of years for a persistent soil moisture deficit to develop and it usually takes a number of years for that deficit to reduce through natural re-wetting and for the soil to expand back to its original condition at field capacity (its maximum water content). For that reason, heave usually occurs over a number of years, it is progressive and, for all practical purposes, it is beyond control once it begins unless anti-heave precautions have been designed into the structure. Heave is different from structural movement that results from the seasonal recovery of a permeable soil, where no persistent soil moisture deficit has developed. In permeable soils, each year the structure will recover back to the level it was built at and no further.

From Figure 9, it is unlikely that a persistent soil moisture deficit will develop on a permeable soil and so removing a tree causing subsidence damage will result in stability after about one season (solid green line after tree felled). However, where a persistent soil moisture deficit has developed on an impermeable soil, it could take many years from removing a tree before stability is achieved because the soil will only slowly re-wet (dashed blue line after tree felled). Building Research Establishment Digest 412 *Desiccation in clay soils* (1996) details a number of methods for estimating ground heave following tree removal (www.bre.co.uk. Using this guidance, a structural engineer should be able to clarify the risk of heave through further analysis. However, such calculations are beyond the expertise of arboriculturists and outside the scope of this document.

Managing structural damage from trees



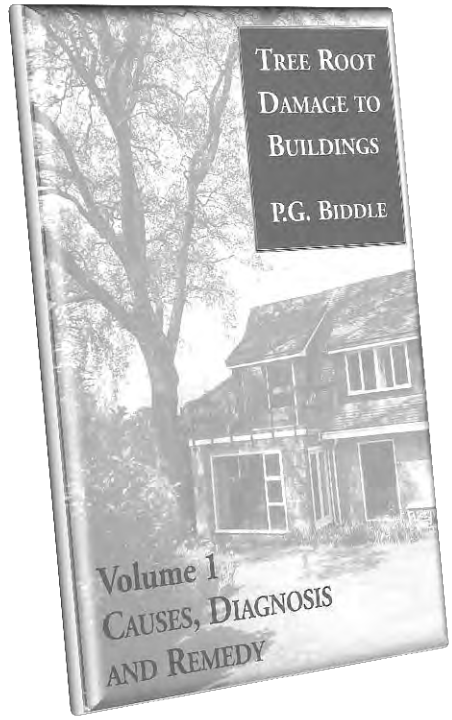
Direct damage reference: A primary reference relating to direct damage from tree roots is The Tree Advice Trust Arboricultural Research and Information Note called *Forces exerted by tree roots* (www.treehelp.info). This provides an engineer's perspective, with helpful case studies that include calculations about the forces that root growth can exert and the type of damage they can cause.

Trees and structural damage

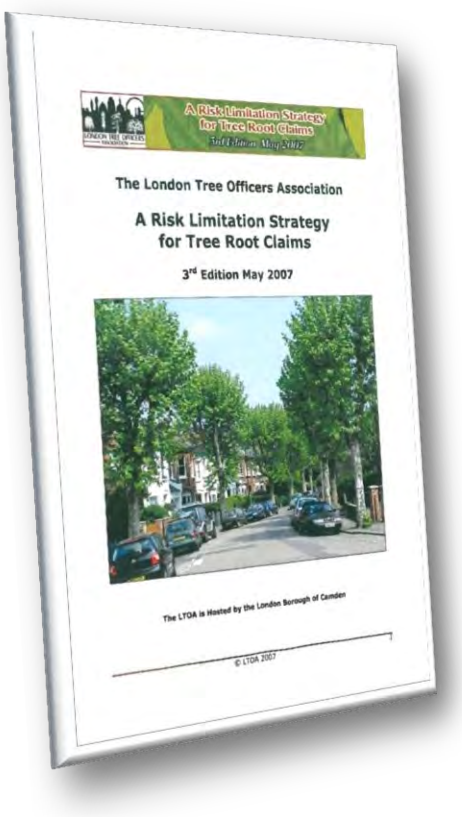
Root pruning established trees: Where established trees are causing surfacing damage, it is often possible to lift the distorted paving, carefully prune any protruding roots and finish with a more flexible surface. These street trees in Amsterdam were successfully retained with the alternative, lighter coloured bonded granular surfacing replacing the conventional paving blocks.

Prevention of damage from newly planted trees: It is possible to prevent surfacing disruption close to tree trunks by installing root deflectors around the planting pit of newly planted trees. In this example in Amsterdam, the roots are deflected downwards and grow out into the surrounding soil at a lower level, avoiding the need to cut large roots close to the trunks as the trees mature (www.deeproot.com).

Trees and structural damage



Subsidence damage reference: One of the most comprehensive references on indirect tree related subsidence damage is *Tree root damage to buildings* by Dr PG Biddle (www.willowmead.co.uk). Its two volumes provide detailed explanations of all the main issues and it is an essential reference for anyone dealing with this type of damage.



Managing the subsidence risk from trees on clay soils: The London Tree Officers Association (LTOA) has a long-standing history of advising its members on how to manage subsidence risk in the London Boroughs. The latest 3rd Edition is called *A Risk Limitation Strategy for Tree Root Claims* and can be downloaded at www.ltoa.org.uk. It advocates an approach based on tree value, where the highest levels of investigation are required for the highest value trees. It has also been instrumental in developing a claim management approach with insurers called the Joint Mitigation Protocol that can be downloaded from its website.

Trees and structural damage

Reducing the risk of subsidence damage from trees to new buildings: The National House-Building Council (www.nhbc.co.uk) has a set of Standards on all aspects of construction and Chapter 4.2 deals with building near trees. This is the primary reference for identifying foundation depths for new buildings near trees using the criteria of distance to the tree, soil plasticity index and the expected mature height of the tree.

Pruning and removal to prevent or stop damage: Pruning trees can significantly reduce the risk of future damage occurring and can stop existing damage, but it has to be severe and it has to be repeated on a regular basis. Tree removal can be an effective solution, provided that heave will not be an issue, and that the trees are not a valuable visual amenity. There is not normally any benefit in phased removal; if the decision to remove a tree has been made, it should be cut down in one go and as soon as possible.

Trees and structural damage

Extent of pruning reference: There is limited research on how effective pruning is at controlling the influence of trees. One of the most commonly referenced project is the East Malling Research and University of Cambridge collaboration published as the Horticulture Link Project 212 (2004) *Controlling the water use of trees to alleviate subsidence risk*. This concluded that for pruning to be an effective means of controlling tree water use, it has to be severe, i.e. crown reductions of up to 70%, and it has to be repeated every two to three years to remain useful.


CONTROLLING WATER USE OF TREES TO ALLEVIATE SUBSIDENCE RISK

Horticulture LINK project 212

Final report – May 2004

emr
east malling research

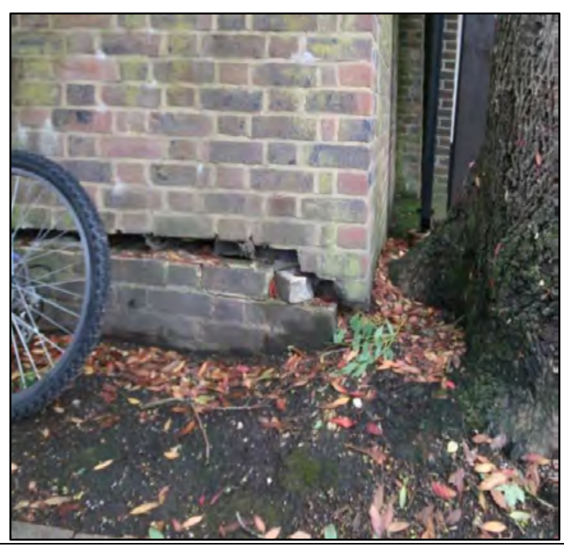
UNIVERSITY OF CAMBRIDGE

Test your knowledge of tree-related structural damage

Below are some common scenarios on the right with explanatory notes on the left.

- Large, vigorously growing eucalyptus next to a boundary wall
- Cracks in the wall are progressively increasing in width year by year
- The soil is a sandy gravel with no clay
- What are the solutions?

- There is no clay so the damage cannot be indirect from soil shrinkage
- Direct root growth can lift small walls and so this is the most likely damage mechanism
- However, transmission of trunk movements may also be contributing to the damage
- Here is an image of the damage three years after the photo on the left



 • A mature oak at least 100 years old • A new building within 4m • The soil is clay • What are the risks?	• If the clay is impermeable, then the tree could have easily built up a persistent soil moisture deficit • A building constructed into shrunk soil will be at risk from heave unless heave precautions have been incorporated into the design • With the appropriate foundations, the tree and the building can co-exist without any significant risk of structural damage
 • Parts of the Tower of London date from the 11th Century • The mature planes are about 120 years old • The soil type is unknown • What are the risks?	• There is no risk of direct damage because the building is too large and the trees are not close enough • There is only a risk of indirect damage if the soil is clay • Although these trees are old and quite capable of having built up a persistent soil moisture deficit, the building is much older and there is no risk of heave • If the soil has shrunk and caused subsidence damage to the building, removing the trees will allow the soil to expand back to its original level, so the building will recover but not lift beyond its original level • Heave can never be an issue in such relationships, but recovery may be

Trees and structural damage

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Two very large redwoods in Southampton about 90 years old
Both are about 5m from the building
The building is about 60 years old
The soil is unknown
What are the risks?

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It is unlikely that there will be a risk of direct damage because the trees are not close enough and, although small, the building is still too substantial for direct root growth to affect its main structure
There is only a risk of indirect damage if the soil is clay
The trees are much older than the building and would have been capable of establishing a persistent soil moisture deficit before the building was constructed, so there was a risk of heave in the early life of the building if the soil is clay

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St Mary's Church in Ely dates from the 13th Century
The yew trees either side of the entrance are at least 120 years old
The soil is unknown
What are the risks?

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There is no risk of direct damage because the building is too large and the trees are not close enough
There is only a risk of indirect damage if the soil is clay
Although these trees are old and quite capable of having built up a persistent soil moisture deficit, the building is much older and there is no risk of heave
If the soil has shrunk and caused subsidence damage to the building, removing the trees will allow the soil to expand back to its original level, so the building will recover but not lift beyond its original level
Heave can never be an issue in such relationships, but recovery may be

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Trees and structural damage

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This house has just been built
The oak trees are about 60 years old, but more than 7m from the building
The soil is unknown
What are the risks?

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There is no risk of direct damage because the building is too large and the trees are not close enough
There is only a risk of indirect damage if the soil is clay
These trees are old enough to have built up a persistent soil moisture deficit and so there could be a risk of heave
There will be a low risk of damage to new houses built taking account of soil conditions and adjacent trees, as set out in the NHBC guidance

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This house in San Jose, California, is about 30 years old
The mature trees are between 50 and 70 years old, and some are within 1m of the building
The soil is unknown
What are the risks?

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Timber framed buildings are generally considered less susceptible to damage from structural movement
There is a risk of direct damage through the transmission of trunk movements to the structure and through root-ball displacement if any of the larger trees blew over
There is only a risk of indirect damage if the soil is clay
If the soil is clay, there could have been a persistent soil moisture deficit at the time of construction because the trees would have been a substantial size at that time, so there was the potential for heave damage
If the soil is clay, there is the potential for indirect damage

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Trees and structural damage

- This house is about 25 years old
- The maturing Leyland cypress on the adjacent property are about 20 years old, and within 2m of the building
- The soil is a sandy gravel
- What are the risks?

- There is no risk of indirect damage because there is no clay
- There is no risk of direct damage to the building because it is too big
- There is a risk of direct damage to the paving because the slabs are much lighter structures
- Damage to the paving had occurred to the paving, as shown below, but there was no damage to the house
- Excavation revealed many roots beneath the paving, which was the cause of the uplifted slabs

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February 2011