Root Barriers and Building Subsidence

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Arboricultural Advisory and Information Service

Summary

Trees may cause damage to built structures by extracting water from clay soil beneath the foundations. Severe pruning or removal of the tree can be unacceptable methods of amelioration. Construction of a barrier between a tree and a building may appear a simple method of preventing root activity near the foundations. However there are limitations to barriers both in their design and materials to use. This Note discusses the role of root barriers, design criteria and materials that might be adopted.

Trees - A Mixed Blessing

Trees are an important feature of both the rural and urban landscape. They are not only aesthetically pleasing by virtue of their size, flowers and autumn colours but also have practical benefits such as improving air quality and providing screening and shade all of which can add quality to people's lives. However, there is a darker side to trees, like the infamous Dr Jekyll and Mr Hyde. Trees can block light, shed leaves, flowers and fruit and cause damage to people and property, for example, by shedding limbs in strong winds. But it is below ground that some of the most serious damage can occur, certainly in financial terms. Roots are the villain of the piece! They can cause buildings on shrinkable clay soils to subside, and they can crack pavements, dislodge kerbs and block drains. Such problems are particularly prevalent in towns where trees often have to compete for space with buildings, pavements, and underground services. Conflict can then arise - the tree owner or manager and the community at large may want the tree to be retained whilst those responsible for repairs to a damaged structure may call for the tree to be removed or roots to be cut back, in order to prevent future damage.

There have been a number of suggestions of ways in which root damage to structures may be avoided. Giving trees more space is the ideal solution, but since this is often difficult other solutions have to be sought.

There is not enough known about either the rooting habit or the water requirement of most tree and shrub species to make meaningful choices for planting near to buildings. Even where general rooting characteristics are known they can be substantially altered by prevailing soil conditions (McPherson and Peper, 1996). Furthermore, varieties of trees desirable for their appearance and size are grafted onto the rootstock of a true species, the mature size of which may be very different from the ornamental form.

Pruning roots is an unsatisfactory option because new roots may colonise the soil and cause damage again. Cutting roots may also lead to shoot dieback and could render a tree unstable. Strengthening susceptible structures is another option, but the cost should be compared with the value of the tree.

Root barriers have sometimes been considered the ideal solution to the problem because they are relatively cheap, and should ensure against damage to structures whilst enabling a tree to be retained. However, root barriers cannot be considered to be a 'cure all' for every situation, but, when designed and constructed to meet specific site conditions, they may assist in reducing the risk of damage to structures, whilst enabling retention of trees. This Note discusses the role of root barriers and indicates why some root barriers have not been as effective as they should have been.

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The Root Cause of Problems

In order to determine whether a root barrier is the best method to solve a particular tree-related problem it is important to understand the nature of tree root growth. Part of the reason that root barriers have not lived up to expectations is because of poor understanding of how tree roots grow and failure to recognise the limitations of barriers. Roots tend to spread outwards rather than grow downwards and the root system can extend radially in any direction distances frequently in excess of the tree's height. Whilst the majority of roots are in the upper 600 mm of soil, some grow down to depths of 1-2m, and exceptionally some species may penetrate as much as 5m (Dobson, 1995). Nevertheless, the thick structural roots which provide stability for the tree trunk are usually confined to within a 2-3m radius of the trunk. These roots taper and divide repeatedly within this distance until they are usually no thicker than a finger and then continue outwards without appreciable further taper for many meters. Smaller roots develop from any part of these roots and repeatedly sub-divide into a network of fine roots which are the principal absorbers of water and minerals essential to the tree's survival and growth. These may be short-lived but new roots develop throughout the growing season to fulfil the water and mineral needs of the tree. The precise distribution of roots in the soil is impossible to predict as root growth is opportunistic, developing wherever soil conditions are suitable. Where soil is inhospitable due to compaction or waterlogging, roots tend to grow predominantly at very shallow depths.


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Building with structural cracking

As tree roots grow they may contact man-made structures such as building foundations, retaining walls, pavements and drains. Roots cannot bore into solid objects, they are usually deflected around, under or over such obstacles. However, roots can cause two types of damage:

- **Direct damage.** Caused by the direct pressure exerted against a structure by tree roots.
- **Indirect damage.** An indirect effect caused by roots taking moisture from shrinkable soils.

This Note primarily focuses on indirect damage.

Direct Damage - A Growing Force

A growing tree root, increasing in diameter, exerts pressure on the soil around it - a steady, persistent, but increasing force. Where a root is in contact with an obstacle (e.g. a rock or building foundation) the force will be transmitted to that object. Because the force generated is relatively small (MacLeod and Cram, 1996), roots are only able to cause damage to lightly loaded structures such as pavings, kerbs, boundary and retaining walls and single skin garage walls - houses are too heavy to be damaged in this way.

It is often asserted that roots damage underground services (particularly pipes). Although roots may be found sheathing a pipe or growing inside it, they are generally not the cause of damage - they can neither detect water in a sound pipe nor exert sufficient pressure to break into a sound pipe to gain access to the water it may contain. However, if a pipe is already damaged and leaking, tree roots may be attracted by the moisture, enter the pipe, proliferate and ultimately cause a blockage (Brennan *et al.,* 1996). Pipes with clay-packed joints are most prone to invasion by roots, particularly as the joints fail. Modern pipes made of PVC plastic and fibreglass and those using rubber sealing rings are resistant if constructed properly.

Indirect Damage - A Drying Process

Indirect damage is a consequence of trees taking moisture out of the soil. It is a feature of clay soils (also peat, but this is less common) As clay soils dry they shrink and they swell as they rewet - sandy, silty and gravelly soils do not do this. Clay soils are therefore usually subject to seasonal movements, shrinking during the summer when temperatures are high, rainfall is low and vegetation is active, and swelling in the winter when soils are able to rewet. Plants exacerbate this seasonal movement. Because tree roots exploit a larger volume of soil than most other plants they can have a particularly significant, but localised, effect on soil moisture content. Nearby structures built with insufficiently deep foundations on shrinkable clays may be damaged. The risk of damage depends primarily on the interaction of the soil, weather conditions, and the foundation depth and method of construction. Tree species differ in their ability to dry soil and as such, consideration of the risk posed to buildings from indirect damage should also include evaluation of the tree species, distance from the building and expected mature height of the tree (for more detailed information see Biddle, 1992). Shrinking of a clay is a reversible process. A clay that swells as it rewets can exert very great pressure which may lift a building (heave) or burst the foundations apart. **It is important, therefore, that before removing the influence of a tree (felling or severing roots) very careful consideration should be given to the possibility of heave occurring.**

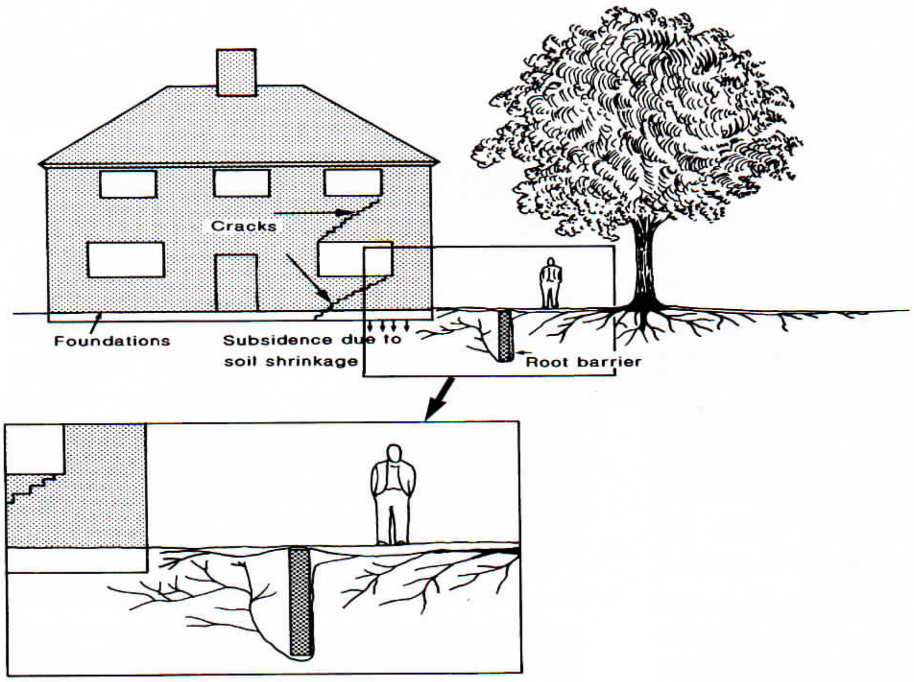
Reducing the Risk - What is Required?

Root barriers are usually considered because they appear to be a cheaper alternative to increasing the depth of foundations by underpinning and because it may obviate the need for severe pruning or felling of offending trees. However, it is not easy to completely isolate a structure from the influence of tree roots. Research on barriers has found that tree roots have an extraordinary ability to find their way over, under or round them. In order to be effective, therefore, great care needs to be taken in the choice of materials and method of installation of a barrier. Careful consideration should also be given to the objectives of a barrier - the requirements will be much more stringent if the intention is to entirely isolate a structure from the influence of tree roots rather than simply reduce the amount of root growth near to a structure. In order to have a reasonable degree of confidence that a barrier is going to be effective it should:

- extend below the likely depth to which roots will grow. It may be insufficient to consider the majority of roots and construct a barrier only, say, 1m deep. It may be necessary to go down 2m, 3m or even 5m, until unrootable conditions are reached (e.g. water table or bedrock). It should also be borne in mind that the digging required to construct the barrier will disturb the soil, improving rooting conditions, and thus, at least in the short term, may increase the potential for root growth. If, as a result, roots are able to grow underneath a barrier they may eventually reach the structure being 'protected'. The barrier may therefore need to be secured to the bedrock, for example.
- protrude above ground level. Any vegetation or debris allowed to cover the top of the barrier may allow roots to grow over it. Once over the top, roots are likely to be able to grow unhindered. Indeed the roots of some species, e.g. poplar, have grown over the top of a barrier even when it protruded well above ground level and had never been covered (Barker, 1994). For a flexible membrane, it may be necessary to embed the above-ground part in a durable material (e.g. concrete) to avoid it being damaged.
- be situated between the structure at risk and the tree. It may be necessary for the barrier to extend either side of the tree a distance equivalent to the anticipated mature height of the tree. However, it should be borne in mind that tree roots can extend up to 3 times the tree height (Dobson, 1995). Building a barrier in an arc around a tree may be a possible solution, but it may need to have its ends at least the height of the tree away from the structure at risk.
- withstand being split, punctured or cracked during installation and by any subsequent differential soil movements. If there is a weakness in a barrier, roots are likely to exploit it - once through, roots will be able to proliferate on the other side.
- be free of any openings or joints through which roots might grow. The barrier should, therefore, be sealed around each and every service or structure that crosses it, but the seal must be capable of allowing the services or structure to move when the soil shrinks or swells more on one side of a barrier than on the other.

- be impenetrable to tree roots. The limited investigations undertaken on some materials used as barriers are not extensive enough to permit comprehensive advice to be given on their appropriateness. The claims of the manufacturers should be regarded with caution as some materials are marketed on the basis of a theoretical rather than experimental appraisal of their effectiveness. Nevertheless, some of the properties that should be looked for in a barrier material are discussed below.

In some situations it may be important that the barrier material does not prevent water movement through the soil (for example, if there is an underground spring). However, permeable materials may only briefly delay the passage of roots (see Appendix) and it may be better to design the barrier so that water movement is deflected rather than stopped..



Root growth around a barrier

Since the backfilled soil is likely to be looser than undisturbed soil, and may allow greater root proliferation and a relatively easy route to the bottom of the barrier, the backfill should be on the side of the barrier nearest to the protected building.

Suitable Materials

Trenches filled with concrete have been specified as tree root barriers. But as concrete has limited tensile strength allowance should be made for the considerable forces that can be created by differential soil movement (Bonshor and Bonshor, 1996), particularly if, as can occur following root severance, the soil rewets and expands on only one side of the barrier. If a concrete barrier cracks, roots may grow through it, but concrete adequately reinforced with steel should be able to withstand the pressures generated by differential soil movement. Sheet steel piling may overcome the problems associated with soil movement, but unless sealed, the joints between individual sheets could provide a pathway for roots.

Tree roots are easily deflected even by apparently minor obstacles to their passage (c.f. polythene pots). More recently, therefore, attention has turned to the use of flexible sheet materials. These have the advantage that they need have fewer or no joints. Examples include geomembranes, geotextiles (both woven and non-woven) and herbicide impregnated geotextiles (see Appendix). Sheet materials used for a barrier should be:

- durable (resistant to biodegradation and photodegradation) throughout the life of the structure and/or the tree - whichever is shorter. As the barrier will need to protrude above ground level where it will be exposed to sunlight, materials such as PVC will be unsuitable (unless protected, e.g. by embedding in concrete at the surface). A problem with some materials specified for use as root barriers is that no-one knows how long they will last. Those that do have a guarantee against degradation are only guaranteed for a maximum of about 20-30 years, but trees and buildings can have considerably longer lifespans.
- resistant to puncture by sharp objects or tearing as a result of soil movements.
- easily assembled/installed. Costs will rise in proportion to the difficulty of installation.

† *The Arboricultural Association maintains a Directory of Registered Consultants available, on request, from Ampfield House, Ampfield, Romsey, Hants SO51 9PA.*

What About the Trees?

Cutting through a tree's root system during construction of a root barrier will reduce the tree's water absorbing capacity. This reduction may be temporary and it will be reinstated when roots have developed elsewhere in the root system to replace those severed - a process that may take many years if a large proportion of the root system is removed. Mature trees, particularly if declining in vigour may die back following root severance or, in extreme cases, may die. In addition, severance of major roots may weaken a tree's ability to resist pathogens. Nevertheless, if a tree is healthy and vigorous it may be able to withstand the loss of up to 20% of its root system without visible effect. However, extreme care should be taken, including seeking specialist advice†, to ensure that the loss of roots does not impair the tree's stability leaving it potentially vulnerable to being blown over. Some general guidance on areas around trees that should be left undisturbed are given in BS 5837 *Guide for Trees in Relation to Construction* (BSI, 1991) and NJUG (1995).

In most trees, pieces of severed root will die. Even if they do not die immediately they will cease taking water from the soil. Some tree species, though, are able to produce new shoots (suckers) from severed pieces of root. Species that produce root suckers include, cherry *(Prunus spp.),* false acacia *(Robinia pseudoacacia),* poplar *(Populus spp.),* elm *(Ulmus spp.),* tree of heaven *(Ailanthus altissima)* and sumach *(Rhus spp.).* If these shoots are allowed to grow they may develop into new trees between the barrier and the 'protected' structure. For a barrier to remain effective such growth should be poisoned using an appropriate herbicide which will also kill roots (do not use such a treatment on the tree side of the barrier as you may inadvertently kill the tree).

Caution!

Where excavation is proposed near to a tree that is subject to a Tree Preservation Order (TPO) or that stands in a Conservation Area, the Planning Department of the local authority should be consulted. Under the terms of a TPO it is an offense to damage any part of the tree (including roots) without permission from the council. It is also an offense to carry out work on a tree within a Conservation Area unless six weeks notice of the proposed work is given to the council. With some exceptions (for example, prevention or abatement of a nuisance, Dobson and Patch, 1997), failure to observe these requirements could lead to prosecution and a fine of up to £20,000.

Concluding Thoughts

Root barriers are not the magic solution to all problems of subsidence where tree roots are implicated. They should be looked upon as one of a range of options available, each of which should be critically examined to determine its appropriateness to the particular situation. **A root barrier should be considered only when it has been clearly demonstrated either that tree roots have contributed to damage, or that there is a real risk of damage occurring.** There is no sense in damaging a tree and causing major upheaval of a site, at considerable expense, where such action will not solve the problem.

There is insufficient information available to make prescriptive recommendations about the best materials and techniques for installation of root barriers. Properly designed and installed barriers may prove effective for many years, but this may depend on the material used, the design of the barrier, the period over which the building is at risk and the condition of the tree. In some cases it may be better to direct resources towards strengthening susceptible structures and changing tree management.

Where tree roots are shown to be implicated in indirect structural damage an effective root barrier would have the same effect on the building as removal of the tree. This is because there will no longer be any absorption of water from the soil by the severed portions of tree roots. Therefore, if tree removal is not considered acceptable from a structural point of view (i.e. because of heave when the clay rewets), then neither is a root barrier a suitable solution.

Whilst the long-term effectiveness of a barrier may be uncertain, it is clear that for some time the influence of the tree will be curtailed. Even if newly developing roots are only temporarily deflected by the barrier, moisture uptake by roots from the region of the foundations may return only slowly, or perhaps never, to the level prior to installation. Thus, to take a 'worst case scenario', **it is likely that a root barrier will be considerably more effective, and for longer, than repeatedly pruning the crown of a tree to reduce its water demand.**

The added advantage of root barriers is that the tree can be retained - provided the tree is able to tolerate the root severance associated with the installation of a barrier. But the limitations of a root barrier should be understood by all parties. However, if the needs of both the tree and the building are catered for and the principles described in this Note are adopted there is potential for a period of many years without further indirect damage induced by tree root activity.

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APPENDIX to Root Barriers and Building Subsidence

Materials for Root Barriers

Although there is relatively little published research on materials for root barriers, there is sufficient information to give pointers on the properties and suitability of some materials.

Non-woven geotextiles

Non-woven geotextiles (e.g. 'Terram') are made of bonded polymer fibres (polypropylene or polyethylene) and are designed to be used as a drainage fabric in civil engineering or as a barrier to prevent mixing of different aggregate layers (e.g. sand and gravel). There have been several studies which have investigated their use as tree root barriers - with mixed results. It appears that the lower (thinner) grades of geotextile (e.g. Terram 1000) allow root penetration relatively easily, but that few or no roots pass through the higher grades (e.g. Terram 4000). In an experiment using trees in bottomless containers, Kopinga (1994) found that roots of poplar *(Populus x euramericana* 'Robusta'*)* were able to grow through all grades of Terram, laid as horizontal sheets under the containers, within one year. Nevertheless, less than one-tenth the number of roots grew through the Terram 4000 compared to Terram 1000. However, in another investigation reported by the same author it was found that no roots had grown through a barrier which had been placed vertically in the soil several years earlier.

Bending and Moffat (1996) conducted experiments with poplar *(Populus alba)* and sycamore *(Acer pseudoplatanus)* in tubes with barriers placed at their base. It was found that Terram 2500 hindered but did not prevent root penetration during the 2-year experiment. Some small roots (<1 mm) were found to have woven their way through the fine interstices between the fibres. The number of roots penetrating was reduced by 75% compared with the control, but the mass of roots was reduced by 90%.

These experiments were of short duration (less than 2 years) and indicate that geotextiles reduce but do not prevent root penetration. Although the numbers of roots crossing such a barrier may be few and their size small, the long-term consequences are unknown.

Woven geotextiles

All the evidence available from experiments involving woven geotextiles indicates that these materials are unsuitable as root barriers. Roots are often able to push apart the strands or fibres making up the geotextile and can thus penetrate through them relatively easily (Wagar and Barker, 1993).

Polyethene (e.g. HDPE)

High density polyethene (HDPE), 1 mm thick, was found to be entirely resistant to root penetration in a 2-year experiment (Bending and Moffat, 1996). Thinner grades of polyethene may be equally effective, but no published information appears to be available. The Heidemij-Scott root barrier is a composite material consisting of polyethene sheeting and a woven geotextile heat bonded together which appears to have suitable properties as a root barrier. The manufacturers claim that there has been no evidence of root penetration or degradation in over 20 years of use.

Reemay Biobarrier™

This root barrier consists of 10 mm diameter hemispherical pellets impregnated with the herbicide Trifluralin, attached to a non-woven geotextile at 38 mm spacings. Trifluralin is released slowly from the pellets and inhibits root growth by disrupting cell division. The evidence from experimental work is equivocal about its effectiveness. Some experiments have shown that it is effective at preventing root penetration (Bending and Moffat, 1996; Tworkoski et al., 1996), whilst others have shown that its effectiveness is variable and seems to be greater with certain tree species (Dosskey et al., 1991; Wagar and Barker, 1993). Gilman (1996) found that no roots grew through 30 cm width Biobarrier placed vertically in the soil, but roots were able to grow under it and back up to the surface. Nevertheless, all the experiments showed a significant reduction in root growth beyond the barrier compared to controls. However, at the time of going to press, Biobarrier was not approved under the Food and Environment Protection Act 1985 and the Control of Pesticides Regulation 1986 for use as a root barrier in the UK.

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