Some Developments in Urban Root Barriers

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Summary In the past, different types of physical root barriers have been used to prevent the structural damage resulting from the drying settlement of foundation clays caused by neighbouring trees. Problems have often been experienced by these barriers, including the normally recommended reinforced concrete barrier, which is also too expensive. To overcome these problems, a method of root barrier installation has been developed progressively through field trials, as revealed in several case studies.

1. INTRODUCTION

Structures founded on clays, especially reactive clays, are known to be damaged by the shrinkage and differential drying settlement caused by the roots of neighbouring trees (Cameron & Walsh, 1981). Various approaches have been tried to solve the problem (Holland & Richards 1984; Nazer, 1991; Pearce, 1993; Smith, 1991), with various degrees of success. One of the most successful and cost-effective methods is the vertical root barrier.

There are basically two types of root barrier: physical barrier and chemical barrier (Nazer, 1991). Chemical barriers have certain disadvantages, such as a limited unknown active life and unknown environmental effects. A major disadvantage of the chemical barrier per se is that it does not prevent moisture flow across the barrier and thus the zone of drying can extend well beyond the barrier.

VicRoads has been experimenting with vertical moisture/root barriers since 1985, when it commenced a research project on the reduction of highway pavement damage resulting from expansive soils (Holden, 1992). In 1990, the scope of the research was broadened to include the damaging effect on adjoining properties of road-side trees in the urban situation.

This paper briefly discusses the problems with past barriers and describes the developments of urban root barriers through several field trials undertaken by VicRoads in co-operation with some city councils.

2. PROBLEMS WITH PAST ROOT BARRIERS

In the past, the most common physical root barriers have been made from reinforced concrete, which has been normally recommended (Holland and Richards, 1984; CSIRO, 1988). Root barriers also have been installed using sheeting of different materials, eg. aluminium, corrugated iron, corrugated plastic and asbestos. In more recent times, special moulded plastic sheets have been used, mainly to prevent roots lifting up footpaths, kerbs, fences, etc. The problems with these barriers are outlined below.

2.1 Not High Enough

Many barriers are ineffective because the tree roots grow over the top. This occurs mainly because the barrier is installed with its top below ground surface (Cameron, 1984; Waters, 1995), or a thin layer of topsoil is later spread over the top of the barrier. The author knows of one case where the roots of a species of fig tree grew through the air to cross the concrete barrier constructed flush with the ground surface. Another common problem is that tree roots grow over a barrier that is installed beneath a footpath or pavement, when a suitable connection has not been formed between them.

2.2 Not Deep Enough

Given an accommodating soil profile, certain species of trees have some roots, called sinker roots, that exist at relatively large depths, i.e. greater than 1.5 m. This type of root was discovered at the Morton Plains Experimental Site during the deepening of vertical moisture barriers in the Second Field Trial (Holden, 1992). In the urban areas, the roots of Plane trees, in particular, have been observed at large depths growing in the bedding material of drains and sewers.

2.3 Not Long Enough

In many cases, the barrier is not made long enough because tree roots have been observed growing around the end of the barrier. This is a problem, particularly in cases where the trench backfill is sand, which provides an easy path for roots alongside the barrier.

2.4 Not Impervious to Roots

Roots seem to have an uncanny ability to detect any holes or cracks in a barrier. Roots have been observed growing through (i) puncture holes in plastic sheeting, produced during backfilling of the trench (Holden, 1992), (ii) joints in barriers made with special moulded plastic sheets (Waters, 1995), (iii) cracks in concrete barriers, and (iv) places of weakness, e.g. areas of bony concrete, in concrete barriers.

2.5 Not Strong Enough

Roots have been observed to penetrate plastic sheeting of insufficient thickness (Landreth, 1991). This ability is a function of the turgor pressure developed at the root tip, which depends on the species of plant (Yau, 1991). Barriers made of relatively brittle materials, such as asbestos cement sheets and corrugated plastic roofing, have been observed to distort and fracture due to either ground movement or radial expansion of roots (Pearce, 1993).

2.6 Not Sealed around Services

Roots often grow alongside service pipes either in the bedding material or in loose soil backfill. They have been observed to grow through gaps between the barrier and the service pipe. One of the greatest challenges for the urban situation has been to develop a waterproof, root-proof and economical seal around each underground service pipe passing through the barrier.

2.7 Not Preventing Roots Growing Underneath

Normally, tree roots on reaching the barrier will be diverted horizontally along it in their search for moisture and nutrients (Holden, 1992). In some cases, especially where sand or loam backfill has been used, roots have been observed to grow down under the barrier (Nazer & Clark, 1982; Waters, 1995).

2.8 Not Flexible Enough

The rigidity of the common reinforced concrete barrier does not cater for the differential vertical movements on each side of the barrier that result from seasonal movements in expansive soils. This may cause fracturing of relatively brittle service pipes that pass through the barrier. Lateral movement in the soil may also cause cracks in these nominally reinforced walls, with subsequent root penetration. These barriers also make it very difficult to replace or repair any services.

2.9 Not Cost-effective

The most commonly used reinforced concrete root barrier has not only experienced the problems mentioned above but is by far the most expensive barrier to install and repair.

3. CASE STUDIES IN DEVELOPMENT OF ROOT BARRIER

Over the last six years (i.e. since 1990), the Special Research Section, VicRoads, has been involved in a R & D sub-project to develop an economical method of installing root barriers that effectively overcome the problems outlined above. This development is revealed in the following case studies.

3.1 Hoddle Street, Collingwood

In 1990, the sub-project on urban root barriers commenced at this site when the Special Research Section was approached to provide a means of alleviating the damage to a brick house, backing onto Hoddle Street, from trees planted by VicRoads in the road reserve.

It was decided to install a root barrier between the fence and the offending trees (mainly Melaleuca Armillaris). A barrier depth of 2 m was chosen based on the maximum depth of the zone of seasonal influence, viz. 1.8 m, previously measured in Melbourne by Holland (1981). This zone of drying produces shrinkage cracks which can provide a path for tree roots that are smaller than the crack (Yau, 1991). A 2 m deep trench, 150 mm wide, was excavated with a modified chain trencher. In places where the basaltic clay was relatively wet, powdered lime was sprinkled onto the chain to prevent the teeth from clogging up. A backhoe, with a narrow bucket, was used to excavate around a service pipe.

A tree root inhibitor (a herbicide called Casoron) was sprinkled onto the bottom of the trench to dissuade roots from growing under the barrier.

A plastic membrane (0.5 mm thick PVC sheet, 2.3 m high) was installed in the trench, on the tree side, using a specially designed membrane dispenser. A later version of this dispenser is described by Evans et al. (1995). The PVC sheet was selected because of

(i) its relatively good puncture resistance and (ii) the ease of gluing it at joins around services and when applying patches over punctures. In areas where near-surface roots were not cut flush with the side of the trench, a piece of woven polypropylene geofabric was laid over the sharp root ends to prevent puncturing of the PVC sheet. The top of this sheet was fixed with roofing nails in the 300 mm excess width folded over the ground surface.

The trench was backfilled mainly with the excavated clay and compacted in the narrow trench with a specially modified air-operated rammer. After top dressing the site with loam, the PVC sheet was trimmed so that it stood upright about 20 mm above the ground surface. This was to ensure that no roots grew over the barrier.

"Saturation" or wetting bores were drilled at 600 mm spacing alongside the spread footings of the distressed part of the house, in order to rewet the foundation clays that had been dried by the trees (Holland & Richards, 1984).

3.2 Summit Road, Noble Park

In 1991, a field trial using a composite plastic membrane was commenced at the site, which contained a single-storey, brick office building that was suffering distress caused by settlement of the front of the building. This settlement was due to the drying effect, of several trees in the front garden, on the reactive clays under the footings. Initially, a consultant had recommended the use of a reinforced cut-off wall as a possible solution. This field trial is reported in detail by Nunn et al. (1992).

During the final preparations for the barrier installation, it was discovered that PVC may be susceptible to having its plasticisers removed by certain types of soils, resulting in a brittle membrane and thus the problem of cracking (Morrison & Swihart, 1990). Therefore, a backing sheet of polyethylene (either LDPE or HDPE) was used to form a composite membrane; this was placed on the tree side of a 210 mm wide, 2 m deep trench, which had been excavated with a mini-excavator (Nunn et al., 1992).

During the placement of the membrane at the Collingwood job, the difficulty of producing a satisfactory, permanent, waterproof and root-proof seal around each service pipe was fully realised. A special polyurethane expanding foam was developed to provide a rapid and economical, impermeable seal and which bonds well to the plastic sheets abutting each side of the service pipe. The method of forming the seal is described by Nunn et al. (1992).

A unique feature of this case was the backfilling of the trench with screenings, which provided a water reservoir to assist in the satisfactory rewetting of the foundation clays, thus avoiding the separate construction of "saturation" bores alongside the footings.

3.3 Melrose Drive, Tullamarine

In 1992, an experimental site was selected on Melrose Drive to test the effectiveness of moisture/root barriers in minimising the drying effect on pavements of two types of trees in the median: (i) existing mature Sugar Gums, and (ii) new Angophora trees.

Because the expansive basaltic clays contained basalt boulders or floaters with diameters up to at least 400 mm, the 2 m deep trenches for the barriers could not be excavated with a chain trencher, but mini-excavators with a 300 mm wide bucket had to be used. Larger rocks had to be first broken up with a hydraulic pick.

Because the backfill consisted of compacted layers of the excavated clay, 1 mm thick HDPE (High Density Polyethylene) sheeting (2.3 m high) was used in order to resist puncturing during compaction. After the first layer of backfill was placed against the membrane, which was suspended on the pavement side of the trench, the root inhibitor Casoron was sprinkled onto this layer, in order to deter any roots growing down the face of the membrane. The 300 to 400 mm layers of basaltic clay were compacted very successfully with a 300 mm wide Stanley Vibrating Plate (Model No. HS-2500) attached to the arm of a mini-excavator.

At one location, in the South Median having the mature Sugar Gums, a polyurethane foam seal was formed around a 300 mm diameter drainage pipe.

Details of the installation methods are reported by Jose (1992), and the initial results from the monitoring of the test sections are reported by Pearce (1993).

3.4 Shelley Street, Elwood

In February 1993, a joint experimental project was undertaken at this site with the St. Kilda City Council (now Port Phillip City Council). Two large Plane trees in the nature strip were causing severe distress to a two-storey block of apartments. In this case, it was decided to experiment with a barrier made entirely of polyurethane foam (PU foam). To overcome our concern regarding the penetration of tree roots, a special formulation of PU foam was developed containing the herbicide Trifluralin. Laboratory experiments were carried out by VIDA (Victorian Institute for Dryland Agriculture, Horsham) to determine the ability of the roots of seedlings to penetrate treated and untreated layers of PU foam. Basically, the roots were observed to penetrate the untreated PU foam but not the treated PU foam. However, roots did grow through a narrow gap beside the treated PU foam layer, along the moisture-coated surface of the clear plastic container.

At the start, a laboratory trial was carried out to investigated the feasibility of creating a PU foam barrier that was 2 m deep and only 70 mm wide, which would adequately seal around a service pipe, 200 mm from the ground surface. This was successfully demonstrated using a mould that could be readily disassembled (Biasizzo, 1993).

A new slim-line boom for a chain trencher was designed and manufactured that excavated a 70 mm wide trench to a nominal 1.8 m depth. To maximise the distance from the trees, the trench was positioned in the asphalt footpath. Prior to excavation, transverse services were located, exposed using an air jet, and then cleaned using sand blasting. Debris in the trench was removed by flushing with an air jet and using a special suction-type evacuator operated by compressed air.

The herbicide-treated PU foam barrier was constructed in 2 m long panels. This was achieved using a specially-designed vertical inflatable form; a custom-built surface "cap" restrained the rising foam (Boyd, 1993). Two inspection wells, one opposite each tree, were installed against the apartments side of the barrier during its construction, in order to primarily observe any root penetration through the barrier.

After one year, significant differential movement had taken place across the barrier, yielding a sharp escarpment, about 60 mm high, in the asphalt footpath. Because this is undesirable and potentially dangerous for pedestrians, it is preferable to position the barrier at the edge of the footpath, furthest from the tree, if possible. The main disadvantage of the PU foam barrier was that the cost exceeded that of a reinforced concrete barrier.

3.5 Drummond Street, Carlton

In May 1993, a joint experimental project was undertaken at this site with Melbourne City Council (M.C.C.). A number of large Elm trees were causing problems with the residents' houses, which were founded on basaltic clays.

Due to the presence of large boulders, a chain trencher could not be used (Pearce, 1993). Instead, a mini-excavator with a 300 mm bucket was used to excavate a 2 m deep trench under the asphalt footpath, just between longitudinal services.

A short time earlier, a new product called Liquifill had come onto the market. It was a cementitious flowable fill or controlled low strength material (CLSM), which had been developed and tested in the USA (Brewer & Associates, 1992). It had (i) a flowable, self-levelling nature that provided an easy and rapid placement, (ii) no compaction requirements and (iii) a relatively low permeability. Liquifill is much cheaper than concrete and can be removed relatively easily by hand tools or backhoe. This flowable fill - comprising sand, cement, flyash and water - was used as backfill against 1 mm HDPE sheets, which were placed on the house side of the trench and overlapped at each service pipe. The flowable fill completely filled any cavities and bonded to the soil in the trench wall on the tree side, thus inhibiting root growth down the barrier.

To prevent the Elm tree roots from growing under the footpath and over the top of the barrier, the following measures were taken:

(a) the stiff HDPE sheet was trimmed about 30 mm above the Liquifill. It was later embedded in the hot-mix asphalt used to repair the footpath, thus providing a physical barrier to any roots, even if the footpath was lifted by their radial expansion.
(b) while the Liquifill was still "green", grooves were cut in its surface to provide a tortuous path for any roots, and;
(c) after spraying the grooved surface with bituminous emulsion, the herbicide Casoron was sprinkled liberally onto the tacky surface.

3.6 Wolseley Parade, Kensington

In June 1993, another joint project with M.C.C. was carried out. At this site, a barrier was required to prevent further damage to several terrace houses from large Plane trees in the road reserve.

At this time, there was a growing concern for the distress caused to the tree by existing excavation equipment, which tended to tear, splinter and strip the bark off large roots thus making them prone to disease. To overcome this problem, special saw teeth were designed and manufactured, and some were fitted to the slim-line trencher boom (Sect. 3.4), as described by Pearce (1993). The new teeth enabled the trencher to efficiently and cleanly cut through roots up to 300 mm diameter.

A mini-excavator with a narrow bucket was used to excavate around some closely-spaced services. As in the previous case, 1 mm HDPE sheets were placed on the house side of the trench, cut around the services, and overlapped. Prior to placement, the overlapping sections were painted with a Trifluralin "paint" to stop any roots that might penetrate the Liquifill backfill. The top of the sheets were stapled to the edge of boards laid along the side of the trench.

A special hopper was made with a narrow throat to transfer the Liquifill from the concrete truck into the narrow trench. Because of the relatively steep slope of the footpath, a sightly drier mix of Liquifill was ordered, so that it did not flow out the downhill end of the trench. Unlike PU foam, Liquifill can completely displace any water that has entered the trench. This advantage was invaluable because the trench was backfilled during torrential rain of the worst thunderstorm in 1993!

3.7 Raglan Street, St. Kilda East

In late June 1993, another joint project was carried out with the St. Kilda City Council. A house on a corner block was being affected by large Plane trees in Raglan Street and the side street (Pearce, 1995).

The method of barrier construction was essentially the same as in the previous case, except for the removal of debris, i.e. loose soil from the trench (see also Sect. 3.4). When the chain trencher works back towards a section that has been already cut, a triangular mound (in the plane of the trench) of soil cuttings forms with a height equal to the trench depth. This situation usually occurs between widely-spaced services, because the complete removal of soil from under each service pipe requires operating the chain trencher in both directions. A special timber ramp was developed that enabled the chain trencher to bring all the loose soil up out of the trench (Pearce, 1993).

4. FUTURE DEVELOPMENTS

The above case studies record the development of a satisfactory method of installing root barriers in the urban situation. However, there are two areas where the barrier installation can be improved.

A method is required that will (i) safely, rapidly, effectively and economically locate services, (ii) excavate a narrow trench around closely-spaced services, and (iii) clean them. Air jetting, used in some of the above cases, created dust and flying stones, was often slow, and became ineffective in hard clays. Some preliminary trials indicate that high-pressure water jetting offers the best hope of achieving the above objectives.

The use of 1 mm HDPE sheeting is difficult to install around the services and hence is labour-intensive, time-consuming and thus expensive. Much of the difficulty is experienced in sealing it effectively around the services, especially deeper ones in the narrow trench. Joining the sheets effectively is a difficult problem that has not been faced. A possible solution to these problems is to eliminate the plastic sheeting by introducing a readily-available waterproofing chemical to the Liquifill backfill. If any cracks do occur, then crystals will grow in the cracks to seal them off against the entry of moisture or roots. It is planned to carry out research on this proposed development with Burnley College, Faculty of Agriculture, Forestry & Horticulture, University of Melbourne.

5. CONCLUSIONS

The problems found with past physical root barriers are that they are often not high , deep, long or strong enough to stop tree roots. Also, roots have been observed to grow under barriers and also through holes and cracks in barriers and through gaps around service pipes. Moreover, the common reinforced concrete barriers are too rigid and expensive.

To overcome these problems, a method of root barrier installation has been developed which includes the following steps:

(a) After locating and exposing the services with air jetting, a narrow (70 mm) 1.8 m deep trench is excavated using a chain trencher with a special slim-line boom. A mini-excavator with a narrow bucket may be required to excavate around closely-spaced services.
(b) A membrane of 1 mm HDPE plastic sheeting is placed on the house side of trench.
(c) The trench is backfilled with a cementitious flowable fill.
(d) After it has set, the top of the backfill is primed with bituminous emulsion and sprinkled with a tree-root inhibitor, followed by the restoration of the footpath.

Further developments are planned in order to overcome some of the limitations of this method.

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