Tree Root Growth Control Series:

Tree Roots And Infrastructure Damage

by Dr. Kim D. Coder, University of Georgia   March 1998

Introduction

Division of space among the many and varied uses in our communities is highly competitive. The economic, environmental, sociological and psychological values generated and managed to assure our quality of life involves an interconnected fabric of biotic and abiotic features. Deeply woven into our developed support systems are natural systems which co-inhabit our useable space. As we concentrate and transport resources to support ourselves, the volumes and surfaces of our spaces become more resistant to the survival of other life forms.

Establishing Blame

The more we sterilize, short-circuit, and usurp natural processes to generate required goods and services, the greater the tendency to relegate remnants of natural systems to nuisance and hindrance. Poorly engineered, designed and installed resource concentration and use systems are susceptible to chaotic failures and ecological changes generating unanticipated results. Blame for negative events are easily shed from inflexible, ill-considered, and inappropriate human endeavors. There will always be some natural biological system available for receiving transference of human ignorance and failure. We are surrounded by operator error!

Tree roots are a common invitee to many of our resource concentration and use structures. Biological illiteracy can be masked for short periods by shear mechanical prowess in building and maintaining structures. We have been conditioned to blame tree roots for a host of engineered and carefully designed failures. Among the scientific community, as other questions are being examined under replicated and controlled conditions, we accept a biased view of cause and effect, and help blame tree roots with only circumstantial evidence. It is concepts engineered to fail and their defenders that burden us.

Role of Roots

Roots do not act as primary causal agents of damage within infrastructures and engineered resource control solutions. Through careful disregard, tree roots are invited into resource concentration areas where valuable and abundant resources are available. As with a full cookie jar left open on the floor in the middle of a play room, a child may be blamed (or even punished) for cookie resource indiscretions, but better solutions are clearly present. The literature is filled with others blaming tree roots for one crime or another. Arborists and community foresters have historically concurred because of the intimate and structural root contact visible among failed infrastructures. As tree managers, we have accepted perception spins delivered to us unquestioningly, and shouldered the blame for our charges.

Tree roots control resource volume or space. In most developed area soils, providing more space for root systems is equivalent to providing more resources for the tree. Roots are designed to carefully sense current soil conditions, and in concert with the rest of the tree, exploit resource space. The growth regulation system of a tree, centered between shoots and roots, assures relatively quick reaction to internal and external environmental changes. The roles of roots are to colonize and hold resource containing space. These roles require elongation, radial expansion, lateral development when needed, continual maintenance of an absorbing system, material transport, food storage, element processing, and survival through poor growth or poor resource availability periods.

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UNIVERSITY OF GEORGIA COOPERATIVE EXTENSION SERVICE FOREST RESOURCES PUBLICATION FOR98-8

Infrastructure Conflicts

The exploration and colonization of resource space position tree roots in seeming conflict with other site uses and structures. Conflicts are most often associated with: sewer or septic lines, storm water drains, water supply lines, foundations, sidewalks, streets, parking lots, pavements (floating and with footings), curbs, walls, swimming pools and structures on dimensionally unstable soils. A preponderance of these conflicts are preventable, with forethought of tree growth over the long-term, and the installation of structures with proper materials and application procedures. Trees will remain an excuse for poor workmanship, bad development, ignorant designs, and incompetent engineering.

Tree roots contribute to modifying their own environment and developing stress and strain on various types of structures. Sometimes the costs of tree-literate design and engineering is greatly outweighed by the cost of correction and cure. The economics, considering all the indirect and direct costs coupled with benefits over tree life, should be examined closely whenever tree or structural treatments are prescribed. Here, I will not review the various methods for evaluating managerial actions economically, but will examine root control options without cost estimates. I will quickly review the economic perceptions in the literature surrounding tree roots and damage to infrastructure.

Economic Impacts of Damage

A survey of cities estimated that total annual cement and sewer line repair bills due to tree roots averaged $4.28 per street tree, which amounted to 25% of tree budgets per year on average (34,35). The same survey found the distribution of repair costs due to tree roots averaged: sidewalks (51%), curb and gutter (17%), and sewers (32%) (35). In a city and county survey, 20% of all trees removed were because of infrastructure damage (35). Tree root damage was the main reason given for tree removal and changing species (4). Another community found 68% of sidewalk damage adjacent to trees (35). A community found 5% of all trees causing sidewalk breaks of at least one inch in height differential, and that 59% of all sidewalk damage was caused by large (30in. (76cm) or larger diameter) trees (35).

In one city 30% (of which 4% were severe damage, 8% were moderate damage, and 18% were minor damage) of all surveyed trees were cited for sidewalk damage and 13% (of which 2% were severe damage, 3% were moderate damage, and 8% were minor damage) were cited for curb damage (57). Of these same trees causing pavement problems, 37% of them initiated infrastructure damage at a distance greater than three feet (57). One community spent $277.78 per mile of sewer line on root control and associated repairs (52). Average costs of tree related sewer repair was cited as $1.66 per tree (35). One community used 40% of its annual tree budget for sidewalk repairs stemming from tree root damage (35).

General costs for sidewalk repair because of tree root damage was estimated to be $500.00 per repair, with a life span of the repair estimated at 5 years if the tree is not removed (53). The most widely surveyed solutions to tree root problems were listed as tree species selection changes, root barriers (only 25% of surveyed believed they worked), and root pruning (poorly accepted and suspected of increasing structural failures) (35). Tree root growth is considered an expensive nuisance and liability risk in many communities.

Physical Aspects of Damage

Tree roots have been cited as causing increased liability risks, management costs, and maintenance costs. Public concerns and other infrastructure manager complaints have included an increased exposure to tree-illiterate, dictated change and symptom treatments (as opposed to treating underlying causes of problems). Some of these quantified values for tree root damage have been recited many times, and are cited as established fact across the arboricultural literature without regard to source, reporting bias, professional review, or analysis. Note that many of these data have been developed using subjective observations, personal memories, general opinions, and unpublished reports. Instead of an exhaustive review of tree root damage effects, I will summarize general trends.

Tree roots are directly involved with damage to sidewalks, curbs, gutters, and to a lesser degree, sewers (35). One community's replacement cycle for sidewalks continually damaged by trees was every 5-10 years (35). Tree roots are cited as opportunists, utilizing structural faults in infrastructure to capture essential resources (35).

Even small diameter roots are able to facilitate pavement damage (28). Tree diameter and species are major controlling factors (80% variation accounted) cited for infrastructure damage (34,35). Managers stated that damage was more site-specific rather than species-specific though (35).

Tree Diameters & Damage

Tree diameter (DBH) is directly related to infrastructure damage. Once trees are well established and start to exceed eight inches in diameter, damage tends to accelerate (28,57). Beyond the root plate area of a tree where damage is common, there was little correlation between how far trees were from roadways and/or how much available rooting volume was provided, and the damage caused (28). Larger diameters could be accepted closer to curbs than sidewalks, due to the additional material strength and placement (21). (Figure 1 (21) & Figure 2 (54)).

Where trees were continuing to damage sidewalks, cement replacement was required on a 5-10 year cycle whether root cutting at the time of cement replacement was part of the treatment or not (35). Soil water levels (wet vs. dry sites) made no difference in the damage frequency to sidewalks (28). Tree diameter measures and distance of the stem to the infrastructure were part of quantifying damage risks. Unfortunately, seldom are non-tree-associated failing infrastructures examined to help visualize the scope of root damage (21).

Infrastructure Damage

Infrastructure age, faults and deterioration are the sources for root colonization that eventually lead to damage. The materials used in construction can lead directly to failure. Asphalt is usually laid down in thinner sheets than cement slabs, has less tensile strength across the surface than cement, and so, is prone to show damage more easily as when compared to cement (57). Cement is strong under compression, but is brittle.

The force required to damage cement from below can be calculated. Let the cement sidewalk slab for this example be four inches thick, five feet wide, and reinforced with a coarse hardware cloth. The slab laying on the ground can withstand approximately 3000 psi when loaded from the top if the slab lays flat on a smooth under-grade. This slab can withstand 330 psi if pushed up on from the bottom. If a small root elevates the slab only a small amount (one inch) with people continuing to walk on the slab’s top surface, only 60 pounds of pressure per inch is required to crack the slab. Over time this a relatively small amount of pressure.

In the case of waste-water carrying pipes, older clay and cement pipes with gasket connections along their length present many avenues for tree roots to colonize over time (35,45). The pipe bed or underlayment can lead to a proliferation of settling faults. Roots growing along the pipes, and developing mass over time, can exert significant new pressures on pipes. Roots pushing into and around gasket connection points radially expand and break seals. Pipe materials that easily transmit temperature changes to their surfaces can provide areas of fracture pore space and available water condensation around the pipe. New plastic pipe materials, solvent welding systems, and proper installation can help eliminate future tree root problems in pipes (45).

Soil Movements

Another infrastructure damaging event often blamed on trees, and used to destroy valuable trees at large distances from infrastructures, is water-powered soil swell and heave. The expansive clays (montmorillonite and vermiculite) and to a lesser degree unique organic soils, shrink and swell over changing water contents (8,18,20). Over 20% of soil areas across the United States contain expansive clays. Without trees present, cracked foundations, broken utility lines, buckled sidewalks, and other damaged infrastructure are the results of volumetric movements of expansive clays (18,39). Differential swelling and drying in areas around infrastructures lead to major, shifting stresses over time (49). Drought periods are especially damaging to structures on expansive clays if the structures are not designed to handle these additional loads (33,49).

Trees can transpire large amounts of water under good conditions. As water is removed from expansive clay soils, soils shrink. Soil shrinkage from this process occurs wherever roots are concentrated. Soil volume changes, primarily shrinkage, can cause damage to infrastructures not designed or sited properly on expansive clays (20,30,44,49). Most solutions other than changing design, materials, and their use, are effective only over the short-run and usually involve significant damage to any tree involved. Tree removal and abusive, periodic crown pruning practices are inappropriate solutions sometimes used to minimize damage (39).

Growth Environments

Tree roots have specific requirements to grow and survive in a soil area. Eliminating any one of the essential resources will prevent root growth. Roots grow near infrastructures because all the essential resources are present. Thermal changes between materials provide pore spaces at a wall, along a pipe, or under the pavement (28). For example, roots will run linearly along the pore space generated at the interface of the soil and curbing (17). Soil backfill may have a lower bulk density than surrounding soil and may take years to approach surrounding soil limitations in oxygen, water, and pore space resources. Backfilling may result in a process of soil fracturing and channel creation (45). Roots will take advantage of these soil openings and associated resources.

Materials used for underlayment of pavements are usually coarse, well-aerated products, like sand. The rest of the soil left in position around infrastructure is usually compacted to some degree, with sub-soil / sub-grade extensively compacted to bear infrastructure weight in use. Many dense building materials have enough thermal mass to keep them away from immediate temperature equilibrium with their soil environment. Materials being out of thermal equilibrium with neighboring materials lead to water vapor pressure changes and water condensation at the interface (along the surface pore space) (3,5,19,20,45). Along and under these dense materials, with limited evaporation, the soils can be at or near field capacity for long periods (28,29).

Pipes made of dense materials have additional thermal interactions with the soil because of liquid temperatures moving inside. The greater the differential of temperatures, the greater chance for pore space development at the soil — pipe interface, for increased maintenance over time, and for water accumulation seasonally or daily. Thermal changes also stress joints, gaskets, and connectors providing opportunities for roots to utilize additional resource space.

Conclusions

Many infrastructures that concentrate and transport required resources for people are poorly designed and built to withstand natural processes over time. These engineering flaws are exacerbated by opportunistic tree roots colonizing new resource spaces. To infrastructure managers, blame for failures are delegated elsewhere — in the case considered here, to trees. Tree professionals have been prone to accept this blame and damage trees to fit them into faulty design, engineering, and maintenance concepts. Predicated upon these areas of concern, professional management of tree root growth is becoming more important.

Literature Cited

Full citations in: Coder, K.D. 1998. Selected Literature: Root Control Methods.
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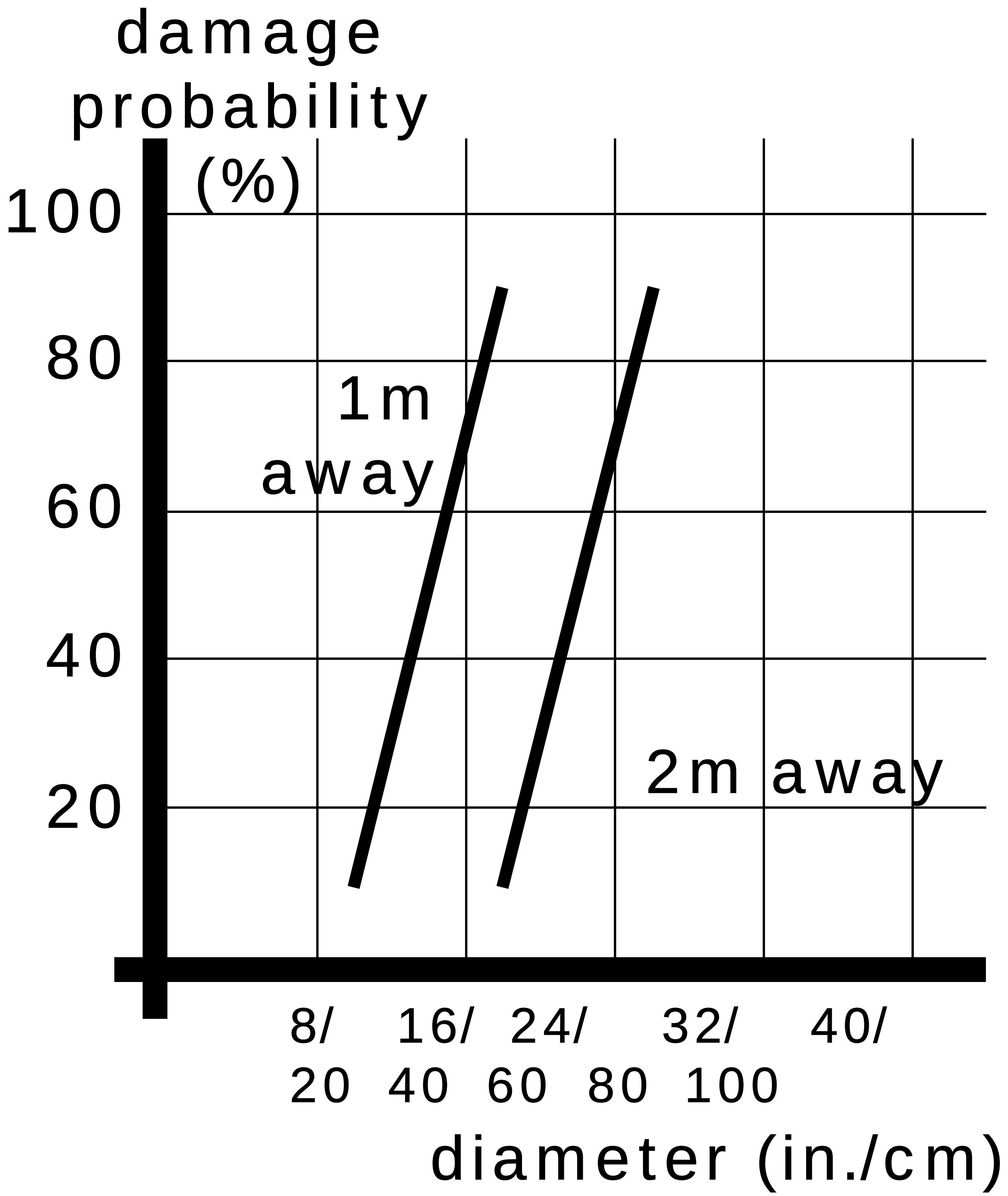

Figure 1: Infrastructure damage potential based upon tree diameter and distance away from infrastructure for one species. (21)

(1 MPa =100 kPa ≈ 1 bar)

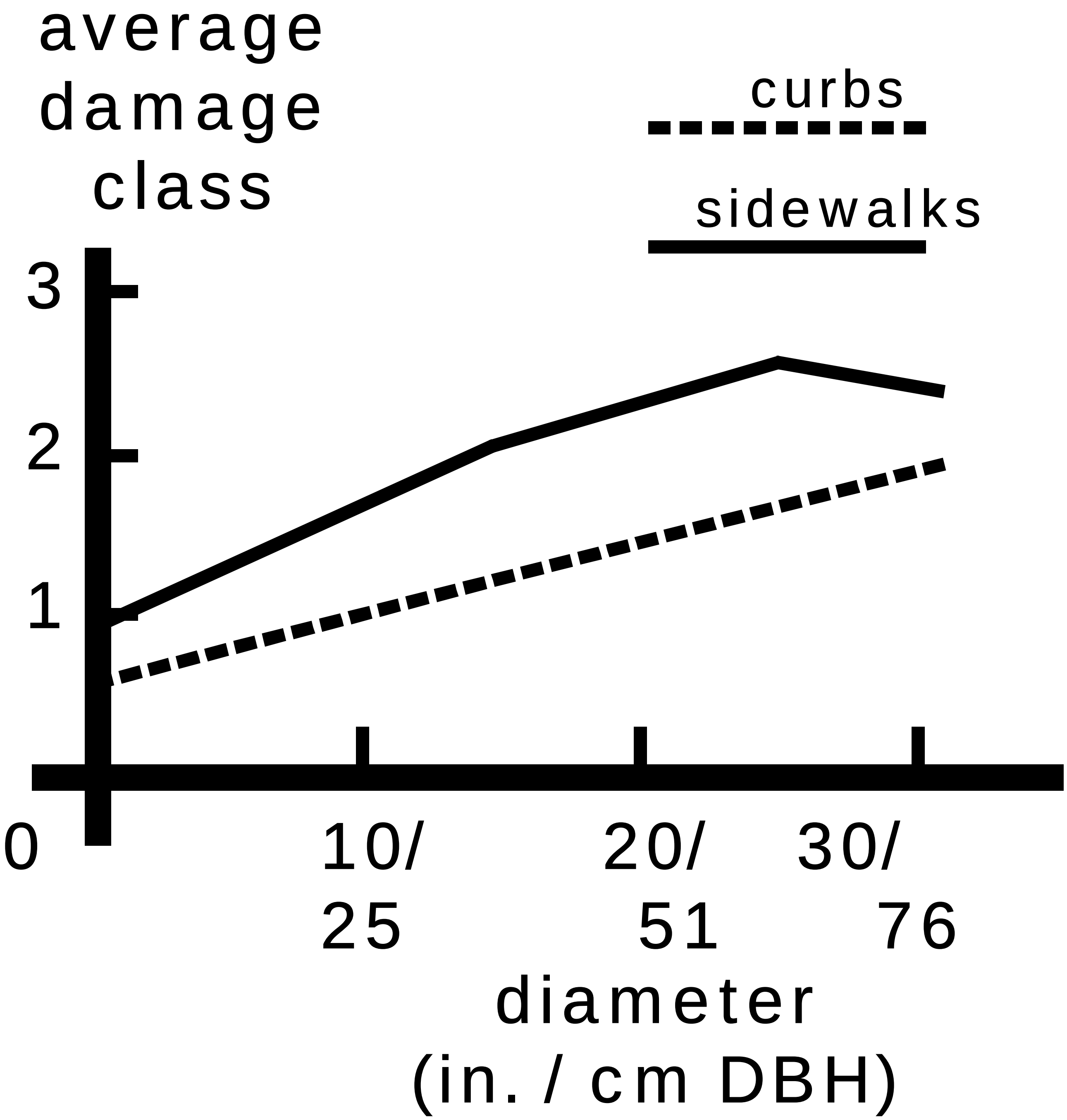

Figure 2: Trunk diameter effects on infrastructure damage. (54)