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Structural and supported soils for trees in hard landscapes – Guide

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Foreword

Publishing information

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The guidance in this document is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Additional commentary, explanation and general informative material is presented in smaller italic type.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

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Introduction

An increasing awareness of the importance of the urban tree canopy cover in maintaining or moderating environmental quality, supporting biodiversity and increasing resilience to climate change has led to the development of programmes of tree planting throughout cities and other built-up areas. However, the challenges to tree growth found in urban environments mean that where these constraints are not managed or resolved, trees can struggle to establish and, consequently, can be stunted, live shortened lives and so fail to deliver the full benefit in terms of ecosystem services.

To meet the competing needs for support of trafficked areas and access for root growth in a common soil volume, integrated design solutions have been developed in the use of “load-bearing” or “structural” soils and non-load-bearing (protected) soils within structural cells. The load-bearing soils include sand-based soils (see [3.11](#)), such as “Amsterdam tree soils”, and stone-based structural soils (see [3.15](#)), such as those developed in the “Stockholm system”. This British Standard provides guidance on the use of sand- and stone-based structural soils and supported non-load-bearing (protected) soils in providing for the establishment and healthy growth of trees to maturity (at least 60 years) in hard landscapes. Some of the soil systems described are relatively new and yet to stand the full test of time; this guidance is, therefore, based upon best understanding, with caveats provided and alternatives presented where relevant.

While general guidance is provided in satisfying the long-term needs of trees in hard landscaping, this document does not cover in-depth aftercare for newly planted trees. For details of the establishment of young trees, see [BS 8545](#). The common techniques, procedures and requirements related to planting trees in non-forest environments are set out in the *EAS European Tree Planting Standard* [[1](#)].

Many of the issues relating to the longevity of trees in hard landscapes examined here are relevant to retaining existing trees in hard surfacing within new planned development; however, practicality might limit how many of the measures described in this British Standard could be applied. Where this is a consideration, reference can be made in the first instance to [BS 5837](#), which details the steps to be taken to help ensure that trees are appropriately retained and protected when a development takes place.

1 Scope

This British Standard gives guidance on water storage, filtration, hydraulic conductivity, fertility, pH, load-bearing capacity (where applicable), volumes, depth of material and stratification of soils to support tree growth in hard landscapes. It also covers how this material is to be placed and guidance for irrigation and root management. The role of tree soils in the filtration of water and sequestration of carbon is examined. It does not detail the structures that might be used for irrigation, nor structures that might provide support for the tree or pavement but does indicate where such structures might be needed.

This British Standard gives guidance on the use and constraints of the different soil media for establishing trees in the hard landscape.

This British Standard gives guidance on root management but does not replace the need for a qualified structural engineer to assess the location of the tree pit in relation to other structures.

It does not cover tree species selection; however, it does provide advice on appropriate rooting volumes for different-sized species at maturity.

NOTE 1 For soil quality and handling, see [BS 3882](#) and [BS 8601](#).

NOTE 2 Tree species selection is covered by [BS 8545](#) and Tree species selection for green infrastructure: a guide for specifiers [2].

2 Normative references

There are no normative references in this document.¹⁾

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 biochar

solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment; it is an additive that can be included in the backfill material or mixed with an inorganic planting material to provide benefits to the tree in terms of nutrients, air and moisture uptake

NOTE 1 Biochar is manufactured to give it properties that make it of value as a soil amendment or for broader environmental management.

NOTE 2 Biochar can be enriched with nutrients through co-composting with suitable organic materials.

NOTE 3 Biochar production needs to be carefully controlled in the source and nature of materials, temperature, residence time, etc. to minimize the risk of polycyclic aromatic hydrocarbons (PAHs) formation.

3.2 compost

solid particulate organic material that is the result of composting and that confers beneficial effects when added to soil, used as a component of a growing medium, or used in another way in conjunction with plants

[SOURCE: [PAS 100:2018](#), 3.17, modified]

NOTE In [PAS 100](#), compost is sanitized and stabilized.

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3.3 crown spread

approximate diameter of the tree canopy

NOTE This is often measured as an average of the diameters measured from east to west and north to south.

3.4 field capacity

amount of soil moisture or water a soil can hold against the pull of gravity after excess water has drained away and the rate of downward movement has decreased after 1–3 days

NOTE While it is related to the structure and texture of the soil, this is not a constant for a particular soil. It does, however, serve as a practical measure of soil water-holding capacity.

3.5 hard landscape

non-living materials in a landscape project, consisting of surfaces and compositions that have been built or constructed, typically durable and permanent providing the backbone and structure to a space

NOTE This is also referred to as hardscape, or landscape construction.

3.6 hydrogel

macromolecular compound that can absorb and retain large amounts of water

NOTE In addition to helping to also achieve uniform blending of the soil mix in structural soils, hydrogels can improve soil structure.

3.7 non-load-bearing soil

topsoil or subsoil provided as a rooting medium for trees in a hard landscape suitable for use within load-bearing structural soil cells or in the planting hole

NOTE 1 Due to the restrictions on soil aeration, non-load-bearing soils have tighter tolerances than those in accordance with BS 3882 and BS 8601, such that anaerobic conditions do not occur at the base of the tree pit. Where the tree pit is part of a SuDS drainage system the soil is even more critical and therefore two different soil characteristics are listed.

NOTE 2 This is also referred to as “supported” or “protected” soil.

3.8 planting hole

hole of sufficient dimensions, created to accommodate the root ball of a newly planted tree

NOTE This is not to be confused with the tree pit (see 3.17), which in hard landscapes generally represents a larger excavated volume.

3.9 root flare

thickened and expanded base of a tree stem at ground level from which buttress roots form

NOTE This is also referred to as “stem flare”, “trunk flare”, “root crown” or “root collar”.

[SOURCE: BS 8545:2014, 3.19, modified – additional names added to note]

3.10 rooting volume

total volume of soil and voids available to the tree’s root system

NOTE A viable rooting volume is a volume which is able to support healthy root growth by the adequate provision of oxygen, moisture and mineral supply within a healthy soil food web. The rooting volume needed to support a tree to a healthy mature size can vary depending on the needs of the tree species, local environmental conditions and the qualities of the growing media.

3.11 sand-based structural soil

soil consisting mainly of medium-coarse sand with clay and/or organic matter fraction intended to support light loading that can be compacted to load-bearing criteria and installation requirements while still permitting healthy root growth

NOTE 1 This is also referred to as Amsterdam tree soil, tree sand and urban tree soil.

NOTE 2 Typically compacted to 95% relative compaction.

3.12 soft landscape

living, growing, horticultural elements in a landscape environment, incorporating the natural and organic components including soil, and consisting of plants, trees, shrubs, hedges, grass, climbers, groundcover and other living materials

NOTE 1 This is also referred to as softscape, or soft elements.

NOTE 2 The natural and organic components might naturally change over time and can be seasonal. They provide habitat for species, contribute to a healthy environment, support nature, biodiversity and sustainability, adding visual appeal and wellbeing.

3.13 soil cell

engineered structural support unit for the protection of non-load-bearing soils installed below the hard landscape

3.14 soil compaction

process by which the soil grains are rearranged to decrease void space and bring them into a state where they are in closer contact with one another, thereby increasing the bulk density

NOTE 1 This can be incidental or deliberate in order to support a structural load from vertical and lateral forces.

NOTE 2 The combination of high soil density and elevated soil strength can directly limit root growth. The large pores in a well-structured soil are important avenues of gas exchange and they are lost when soils are compacted to high bulk densities. Soil compaction also reduces the rate of water infiltration, the availability of water to roots, and the root system's ability to support a healthy crown.

3.15 stone-based structural soil

growing medium that can be compacted to load-bearing criteria and installation requirements while still permitting healthy root growth

NOTE This is also known variously as skeletal soil, structural soil, gravel-based structural soil or the Stockholm system.

3.16 sustainable drainage systems (SuDS)

drainage systems designed to manage stormwater locally (as close to its source as possible), to mimic natural drainage and encourage its infiltration, attenuation and passive treatment

NOTE This is also referred to as sustainable urban drainage systems.

3.17 tree pit

excavated area, by volume, to accommodate the root system of a specified tree at the time of planting

NOTE 1 The hole excavated generally needs to be larger in hard landscapes than in soft landscapes to enable the establishing root system to have access to sufficient good quality soils.

NOTE 2 Use of this term can be misleading where it infers a confined space of fixed volume available to the roots. This is only accurate where the walls of the pit represent a barrier to root growth. In most instances the rooting volume ought to and will extend beyond the dimensions of the excavated hole.

NOTE 3 Tree pits generally do not need to be more than 1.5 m deeper than the finished level, unless the benefits to the tree outweigh additional engineering costs and buildability considerations.

4 Soil volumes

4.1 The importance of soil volume for tree growth

The soil provides many tree resources, primary among them being water, oxygen, nutrients and a volume to allow stabilizing root growth. When soil volume is limited and/or soil quality is poor, tree growth suffers because the top growth of the tree is dependent on what the roots can provide.

The soil volume into which trees can root and the quality of the soil influences early tree survival and long-term growth and there is a correlation between the provision of an adequate rooting environment and the achievement of canopy potential. Crucially, small volumes might not hold and release sufficient water to meet the transpirational demand of the tree, which leads to water stress and, ultimately, death. Inadequate soil volume and poor soil quality are some of the main contributors to the premature mortality of urban trees.

Trees bring significant benefits to the urban environment, in, for example, cooling through shade and evapotranspiration, the reduction of air-borne particulates and the sequestration of carbon. In order to fully benefit from these effects when designing urban spaces, it is advisable to determine that both the quality and volume of the soil are sufficient for the tree to be healthy through to maturity.

NOTE Adjacent trees often share soil because root systems can overlap and interconnect. This means that there might be a reduction in the volume needed by each tree where the tree pits connect.

4.2 Rooting volumes

4.2.1 General

The volume, distribution, type and quality of soil available for tree rooting in a particular location should be investigated, calculated, recorded (and, if necessary, marked on a plan) by a competent person. This information may be used by designers to specify the location and size and species of trees that could be planted and/or the volume of soils that need to be imported to support planting. This exercise should be carried out early in the process because options might be limited late in the design stage. Where trees are surrounded by hard landscaping, the volume of soil available to the tree can be extended to create a functional rooting environment beneath a hard surface by using soil cells or structural soils (see [Figure 1](#)).

When a tree's root system has become established, it needs a reliable supply of water to sustain healthy growth and development. In urban situations, this can be challenging, especially where the tree pit is surrounded by compacted soils and underground features that impede the lateral movement of groundwater through the soil. Essentially, the soil in a tree pit should hold enough water in storage to meet the tree's needs until the supply is replenished. In most urban situations the most critical role of the soil in the tree pit is to store water for tree growth. Factors external to the tree such as air temperature, wind speed, relative humidity and light help determine how fast water is lost from the leaves. Therefore, trees planted in exposed locations need larger soil volumes than those given in [Table 1](#). Many studies regarding soil volume requirements for different tree types/sizes/species have been based on the water holding abilities of the soil specified, and the anticipated climatic condition expected at the planting site. These factors need to be understood when considering species selection and soil type.

Trees planted in non-compacted soils or pavements suspended by underground cellular systems generally outperform those planted in structural soil mixes of equal rooting volume. However, the water holding capacity, biological health and nutrient availability of coarse textured soils can be greatly improved by adding biochar and compost (see [Clause 10](#)).

4.2.2 Rooting volumes for trees in hard standing

Although variables such as the size of the tree canopy, site micro-climate conditions and tree species greatly influence adequate soil volumes, a few generalities can be drawn.

If soil resources beyond the minimum are available, then encouraging roots in the direction of the additional soil such as adjacent green spaces via channels of rooting soil can benefit the tree in the long term.

Root development outside of the planting pit into adjoining ground is beneficial for the health and longevity of the tree. Where there is risk of direct or indirect damage to structures or surfaces as a result of root penetration, root barriers should be applied. Linking tree pits to “in-situ” native soils might be beneficial not only to increasing rooting volume, but also to enable movement of soil organisms, including soil macro and mesofauna, into tree pit soils that might have limited populations or diversity of such organisms. Soil macro and mesofauna is important to nutrient cycling and soil structure so enabling greater diversity and populations of such fauna in tree pits might benefit soil quality. Wherever possible and appropriate, locally native soils can be utilized to backfill tree pits, to optimize the sustainability of schemes by utilizing a locally available resource. [Annex A](#) gives further information on potential risks associated with urban soils.

Guidance for the minimum volume of non-load-bearing and structural soil related to tree size is provided in [Table 1](#).

NOTE The guidance provided in [Table 1](#) cannot easily be applied to fastigate tree varieties. For cultivars with narrow crown diameters, it is advised that a suitable soil volume is calculated based on the expected water consumption of that variety at maturity in the planting location being considered.

Table 1 — Recommended rooting volumes for trees in hard standing

	Ultimate size of tree				
	Very small	Small	Medium	Large	Massive
Mature height ^{A)}	<5 m	5 m–10 m	10 m–15 m	15 m–25 m	>25 m
Mature crown spread	<4 m	4 m–6 m	6 m–10 m	10 m–14 m	>14 m
Recommended minimum volume of a non-load-bearing loam soil (per tree)	6 m ³ (5 m ³ if shared)	12 m ³ (9.5 m ³ if shared)	20 m ³ (16 m ³ if shared)	28 m ³ (24 m ³ if shared)	36 m ³ (30 m ³ if shared)
Recommended minimum volume of a stone-based structural soil, or a sand-based structural soil (per tree) ^{B)}	12 m ³ (10 m ³ if shared)	24 m ³ (19 m ³ if shared)	40 m ³ (32 m ³ if shared)	56 m ³ (48 m ³ if shared)	72 m ³ (60 m ³ if shared)

^{A)} Mature tree sizes are listed in *Tree species selection for green infrastructure – a guide for specifiers* [2].

^{B)} These soil volumes are only valid for the structural soil blends recommended in this British Standard.

4.3 The planting hole

The planting hole is the opening within the tree pit designed to accommodate the rooting system of a newly planted tree. This should not be confused with the tree pit, which is the larger volume around the planting hole.

The surface of the planting hole should be as large as possible. Ideally, it should be a permeable surface to allow the supply of air and water to the root system. Although the surface of the planting hole can be covered, it is preferable that it is soft landscaped (e.g. mulched and cover planted) and protected using low level barriers, as this reduces soil compaction from traffic and increases infiltration rates. The newly planted root ball can be protected by a “bridge” such as a surface level tree grille, which protects against localized compaction whilst still allowing for gaseous exchange and water ingress. These should be checked regularly and repaired or removed when no longer needed.

The incremental growth of trees should be recognized in the selection, installation and maintenance of materials laid above the planting hole. Rigid surface materials laid up to the base of the tree are likely to cause damage as the tree grows. An engineering solution such as a protective collar could be used to avoid such damage; however, precautions should be taken to prevent the engineering solution itself from causing any damage to the tree. Detailed guidance on this subject is given in *Surface materials around trees in hard landscapes* [3].

When the planting hole is surrounded by hard surfacing its surface can be physically protected by installing railings around the perimeter of the unprotected soil.

The supplier of the tree should confirm root system dimensions before the planting hole is complete. The planting hole should ideally be at least 200 mm in each dimension beyond the root system to allow for adjustment of the tree in-situ.

Figure 1 — Key elements of a planting system in hard surfacing

