2

GREEN BUILDING REFERENCE MANUAL

SOIL REQUIREMENTS FOR HEALTHY TREES

A publication by GreenBlue Urban

This booklet forms part of the **Green Building Reference Manual** for promotion of sustainable urban spaces

Designed to assist landscape architects, civil engineers and consulting arborists, each booklet addresses a key aspect of achieving healthy tree growth in urban contexts. Scientific and technical issues are outlined then linked with available solutions and implementation.

2.1
SOIL REQUIREMENTS FOR HEALTHY TREES

Key issues

Trees require an adequate supply of loose, well aerated, moist and uncompacted soil in order to thrive. These conditions enable the tree's roots to obtain nutrients, oxygen and water – all essential for healthy tree growth. Fig 2.1.1 & 2.1.2

Fig 2.1.1 & 2.1.2 - Trees are frequently observed in cities either failing in the face of hostile growing conditions, or surviving and causing damage to pavements.

Fig 2.1.3 - the availability of space for tree roots to develop is crucial to the tree's ability to grow and stay healthy. In the natural environment, the roots of a growing tree will extend far into the surrounding soil to more than twice the width of the mature tree's canopy.

Fig 2.1.4 - Pavement damage caused by shallow rooting.

Trees obtain nutrients from soil via the roots, but the roots also need the oxygen and water that occupy voids between soil particles. In uncompacted soil, voids are abundant.

For trees in hard surfaced areas, a fundamental conflict exists between maximising the soil volume available for tree rooting while also providing a stable base for roads and pavements. If soil is treated as a structural material and required to bear the load of pedestrians, building and roadways, it will be consolidated to the point that air and water are excluded and insufficient space is available for roots to grow. Fig 2.1.4

Tree roots are opportunistic, seeking out favourable growing conditions. To satisfy the needs of the tree, roots will explore the space below permeable pavements where moisture will be trapped, oxygenated sand layers, moist conditions in service trenches, cracks in road pavements and curbs.

Trees growing in typical urban 'tree boxes' are usually surrounded by compacted soil. This often leads to the roots seeking out the space between the compacted soil and the overlying pavement, where air and water are present, which then causes footpath heaving. Fig 2.1.5

Fig 2.1.5 - Insufficient soil volumes produce damaging, shallow roots.

If the tree roots cannot expand into the surrounding soil, they continue to grow until they have filled up the available space.

When the tree's needs for nutrients, air and water can no longer be met, the health of the tree will begin to decline and it will eventually die. Trees grown in these conditions rarely reach their full growth potential and cannot provide the wide range of benefits that mature, healthy trees have to offer.

Tree roots are opportunistic, seeking out favorable growing conditions. Moisture trapped beneath impermeable pavements, oxygenated sand layers, moist conditions in service trenches, cracks in road pavements and curbs- these are some areas that tree roots will explore to satisfy the life needs of the tree.

Wildlife and biodiversity *– "Urban forests help create and enhance animal and plant habitats and can act as "reservoirs" for endangered species (Howenstine 1993). Urban forest wildlife offer enjoyment to city dwellers (Shaw et al. 1985) and can serve as indicators of local environmental health." (VanDruff et al. 1995).*
Sustaining America's Urban Forest

How much soil do healthy trees need?

The old method of providing an area the size of the pavement opening is clearly insufficient and commits the tree to an untimely death or results in a life time of costly pavement repairs.

Careful assessment needs to be done of the above and below ground space required for each tree to reach its mature size. Various methods, described below, may be used to calculate the below ground space required for healthy root growth and thus the desirable soil volume.

As a general rule feeder roots grow in the top 150-300mm of the soil. This feeder zone can extend two to seven times the diameter of the canopy drip line. Major structural roots may penetrate to depths of 1-5 metres. All trees must be protected from compaction in the feeder zone. **Fig 2.1.6 & 2.1.7**

Resistance of soil to root penetration, or soil compaction, will affect tree root growth.

Soil quality *– "Trees and other plants help remediate soils at landfills and other contaminated sites by absorbing, transforming, and containing a number of contaminants."*
(Westphal and Isebrands 2001).
Sustaining America's Urban Forest

Fig 2.1.6 - Exposed tree root system showing shallow penetration due to heavy, compacted sub soils.

Fig 2.1.7 - Tree root systems include sensitive root tips and minute root hairs, as well as structural roots.

Mature canopy method

Probably the simplest method for calculating soil volume is to estimate the projected canopy area of the mature tree then multiply by a depth of 0.6 meters.
Fig 2.1.8

Fig 2.1.8 - Multiply Projected Mature Canopy Area x 0.6 meters for target soil volume.

As a guide:

- for large trees, allow 10 meters for canopy development
- for medium trees, allow 6 meters for canopy development
- for screens, shelter belts or park group planting, allow s3 meters
- allow 2.5 meters as an absolute minimum in intensive urban developments

Mature trunk calliper method

Trunk diameter is another predictor of root spread. For young trees [less than approximately 20cm in diameter] the ratio of root radius to trunk diameter has been found to be about 38:1. Thus a 15cm diameter tree at maturity can have a root system that extends nearly 6m out from the trunk.

Suggested soil volumes

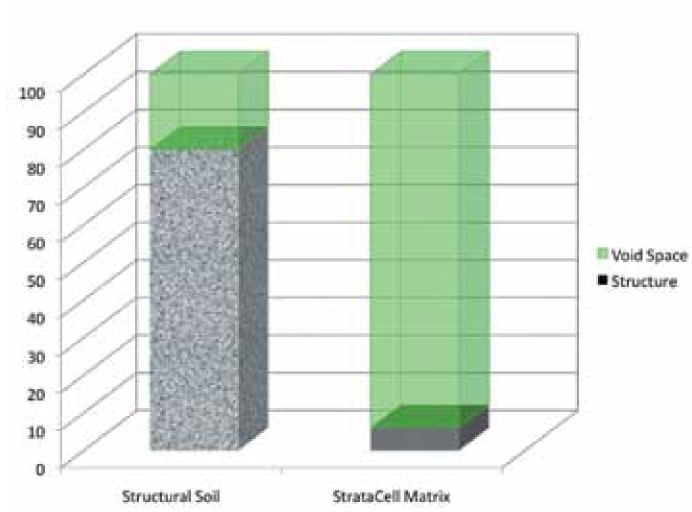
Suggested soil volumes at a minimum are:

Small tree	5-15 m^3
Medium tree	20-40 m^3
Large tree	50+ m^3

Suggested soil volumes, as a minimum:
Small Tree, 5-15m^3
Medium Tree, 20-40m^3
Large Tree, 50-80m^3

"Nationally, urban forests in the United States are estimated to contain about 3.8 billion trees, with an estimated structural asset value of $2.4 trillion."
United States Department of Agriculture Forest Services

NOTE: For a comprehensive soil volume and treepit costing tool, visit www.greenblue.com/soil-calculator



Avoiding soil compaction

‘Structural root cells’, and before that ‘structural soil’, have been devised to address this dilemma of providing uncompacted soil for the trees while allowing durable roads and pavements to be built.

Early methods focussed on a rock and soil mixture known as structural soil to provide pavement support, while permitting some root growth beneath the pavement. Since then, structural cells have moved this principle forward by replacing the rock (which had been 80% of total volume) with engineered modules (6% of volume).

Structural soil

Structural soil comprises large gap graded gravel mixed with a horticultural soil, compacted to 95% of peak density. The gravel compacts to provide the weight bearing capability while the soil, occupying at most 40%, provides for the needs of the tree.

This method has been used with some success however there are extensive considerations to deal with including very specific requirements for the aggregate, precise calculations of voids, tree root diameters and compaction, consideration of climatic factors, choice of filler soil, mixing and compaction methods and measuring. A tendency to soil alkalinity over time limits the choice of tree that can be grown, while subsoil drainage, aeration and feeding are further requirements. Finally the level of compaction required to provide pavement support seriously restricts the development of mature, woody tree roots.

Structural root cells

Structural or root cells are modular units that assemble to form a skeletal matrix, situated below pavement level, to support the pavement load while providing a large volume of uncompacted soil within the matrix structure for root growth.
Fig 2.1.7

Fig 2.1.7 - High strength engineered soil cells permit large trees to be grown in road islands.

Various designs are available on the market providing from 90% to over 94% of space for soil. Different designs address the need for strength while maximising available space for roots as well as for common conduits and service pipes.

Industry professionals are increasingly insisting on the use of structural root cells. They recognise that while structural root cell technology builds upon the earlier structural soil concept, it is clearly superior in performance. Not only is vastly more soil made available to the tree, installation is straight forward and avoids the need for the extensive calculations and testing required for the use of structural soil.
Fig 2.1.8

Tree roots will grow as deep as soil type, oxygen levels, or available moisture permit.

Individual well-being and public health *– "The presence of urban trees and forests can make the urban environment a more aesthetic, pleasant, and emotionally satisfying place in which to live, work, and spend leisure time (Dwyer et al. 1991; Taylor et al. 2001a, 2001b; Ulrich 1984). Urban trees also provide numerous health benefi ts; for example, tree shade reduces ultraviolet radiation and its associated health problems (Heisler et al. 1995), and hospital patients with window views of trees have been shown to recover faster and with fewer complications than patients without such views." (Ulrich 1984).*
Sustaining America's Urban Forest

Fig 2.1.8 - Soil Volumes beneath urban roads can support healthy trees.

2.2
SOIL
TYPES

Key issues

Soil is the uppermost layer of the Earth's crust and is the medium in which trees grow and spread their roots. Soil is comprised of finely ground rock particles of materials such as sand, clay, silt and gravel, with voids between particles containing water and air. Soil may be mixed with larger aggregate, such as pebbles or gravel. Not all types of soil are permeable, such as pure clay.

Soil type usually refers to the different sizes of mineral particles in a particular sample. Each size plays a significantly different role. For example, the largest particles, sand, determine aeration and drainage characteristics, while the tiniest, sub-microscopic clay particles, are chemically active binding with water and plant nutrients. The ratio of these particle sizes determines soil type: clay, loam, clay-loam, silt-loam, and so on.

Sandy soils have very large particles allowing water, air and plant roots to move freely. At the other end of the spectrum Clay particles are so small that they pack together tightly and leave little room for water, air or roots.

Provision of adequate volumes of quality soil for trees in public spaces is essential to long term success.

Ultimately, tree size is relative to available soil volume, oxygen and nutrients in the soil and moisture holding capacity, besides genetic and environmental factors.

"There are over 6 million street trees in California and these trees are associated with approximately $70 million in expenditures to remedy conflicts between root growth and hardscape. This is a conservative estimate because it does not include repair costs for damage to irrigation and water meters, sewer lines, building foundations, parking lots, and pavement on private property. Although data are lacking, a full accounting of repair costs associated with trees on private lands as well as along streets in California would probably exceed $100 million."
Journal of Arboriculture 26(6): November 2000

Nutrients

Seventeen essential plant nutrients have been identified. Carbon and oxygen are absorbed from the air while the other nutrients including water are obtained from the soil, absorbed by the tree's roots. The primary nutrients are:

- nitrogen (for healthy leaf and stem growth),
- phosphorus (for root growth) and
- potassium (overall plant health, especially the immune system).

Secondary nutrients are calcium, sulphur and magnesium, while a range of other trace elements are also needed for healthy growth.

Organic matter

In addition to the mineral composition of soil, humus (organic material) also plays a crucial role in soil characteristics and fertility for plant life. Organic matter is dead plant or animal material. Organic matter improves sandy soil by retaining water and corrects clay soil by making it looser so that air, water and roots can penetrate. In all soils, it encourages beneficial microbial activity and provides nutritional benefits.

Soils change in composition and appearance with depth creating what is known as a soil profile. A typical soil profile has a top layer of decaying organic matter formed by fallen leaves and debris that have been deposited by plants – this layer, if present is sometimes called the O horizon. Below the humus is topsoil, or A horizon, which can range in depth from a few inches to several feet and this is where most tree roots are concentrated. This layer has minerals, decomposed organic matter, and is generally dark brown or red brown in colour.

Under the topsoil is the subsoil, or B horizon, which generally lacks humus and therefore has poorer nutritional value for plants. If oxygen levels are sufficient, and drainage is adequate, tree roots can penetrate into this layer. **Fig 2.2.1 & 2.2.2**

Fig 2.2.1 - Proposed Filler Soils should be specified and approved by a competent soil scientist.

Below the soil layers lies the parent material or C horizon, which is the main source of soil. This material can be a transitional or soft stone layer, or heavy clay. Organic activity and weathering do not affect this layer, unless it is exposed through heavy erosion or construction activity.

The makeup of natural soil is constantly changing as organic material from trees and other plants are added and eroded by wind and water. Many soils are teeming with animal and insect life as well as bacteria and fungi. Earth worms feed on organic matter and break it down whilst creating small tunnels and tracks through the soil helping oxygen to be transmitted.

Cation exchange

Nutrient uptake in the soil is achieved by cation (positively charged ion) exchange. Root hairs pump hydrogen ions (H+) into the soil which displace cations attached to negatively charged soil particles, making the cations available for uptake by the root.

The root and in particular the root hair, is the most important organ for the uptake of nutrients.

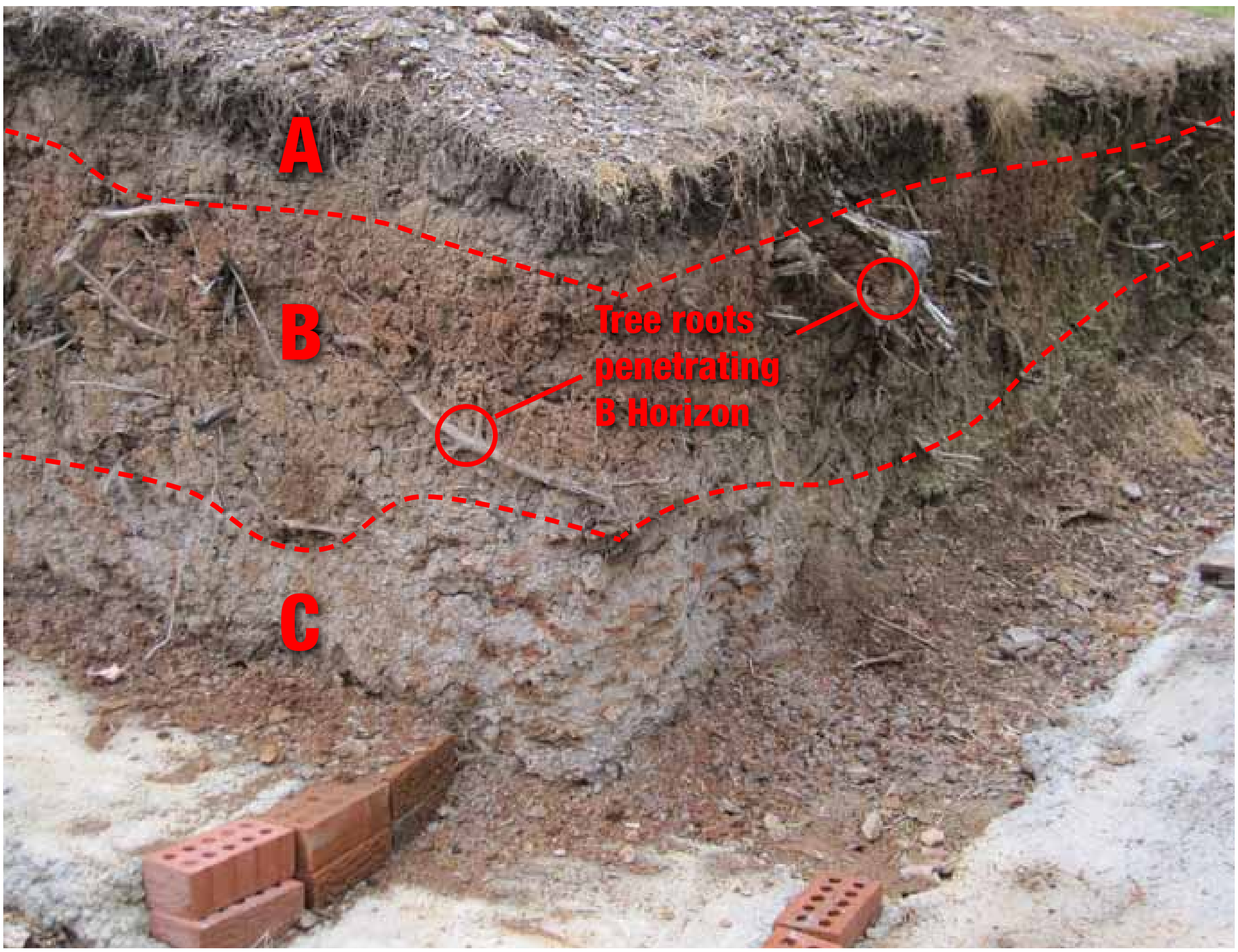


Fig 2.2.2 - Exposed soil profiles at building sites often show the typical compositions as described above.

2.3 ENGINEERING AND PAVEMENT DESIGN

Key issues

Pavement has several key purposes:

- to support loads without excessive cracking or deforming
- to provide a smooth surface for vehicles to improve comfort and efficiency
- to eliminate drainage problems such as mud and ponding

Pavement types - flexible, rigid and composite

Pavements typically consist of a number of layers, placed over the in situ material, which work together to withstand traffic and environmental conditions. The surface layer may be made of concrete, asphalt, aggregate, geocells, grids or blocks. Concrete provides a rigid pavement structure while almost all other pavements are flexible. Composite pavements, often the result of pavement rehabilitation, also exist comprising both flexible and rigid elements.

Fig 2.3.1

Fig 2.3.2

Road pavements are designed to support National Wheel Load Standards, for all pavement types, both rigid **Fig 2.3.1**, and flexible **Fig 2.3.2**.

Healthy trees within carparks provide shade, greenery and potential for Low Impact Design principles including water harvesting.

Soil texture is the amount of sand, silt and clay (large particle size to small particle size) in any soil. This affects water infiltration and retention, aeration, nutrient capacity and retention, and root and plant growth.

"Trees take up large amounts of water from the soil during the growing season. For example, measurements from a fully grown lime tree (crown diameter approximately 14m) in Malmo, Sweden, in summer 2006 showed that that particular tree consumed around 670 litres of water per day during the month of July. Therefore trees have a huge capacity to handle stormwater."
City of Stockholm

Pavement types - porous and non-porous

Whether rigid or flexible, paving materials may also be porous or non-porous. Porous (or permeable) materials have open voids between their particles or units allowing the movement of water and air around the paving material. While some porous paving materials are almost indistinguishable from nonporous materials, their environmental effects are quite different.

Porous paving materials include the following: pervious concrete, asphalt and turf; single sized aggregate; open-jointed blocks, resin bound paving, bound recycled glass porous paving.

The overwhelming benefit of porous paving is its contribution to growing healthy urban trees through the admission of vital air and water to their rooting zones. Porous pavements behave almost like a healthy natural soil surface enabling the soil moisture to fluctuate with rapid wetting followed by drying and re-aeration. Other advantages of porous paving include better management of urban runoff, resulting in less erosion and siltation, and control of pollutants particularly heavy metals and oil through capture and breakdown in the subgrade.

Disadvantages include: the inability of porous pavements to handle large storm events alone; possible soil and ground water contamination; climatic limitations for example road salt and sand cannot be used on porous pavement surfaces; cost, longevity and maintenance. These issues can usually be managed through integrating porous pavements with standard stormwater facilities and careful siting of porous areas.

Load dispersion with depth

Rigid and flexible pavements distribute traffic load differently to the layers below, necessitating careful attention to design and construction of the layers and the thickness of the surface layer. Protection of the base layer, the structural layer nearest to the surface, and the sub-base layer below this, is essential for the longevity of the road.

Because the rigid surface structure does not bend, a point load is spread rapidly over a wide bearing area. By comparison a flexible structure, for example asphalt, flexes to accommodate traffic load. A flexible surface laid over an aggregate base spreads the traffic load gradually to the layers beneath. In this case a thicker pavement structure is required to protect these layers to the same degree.

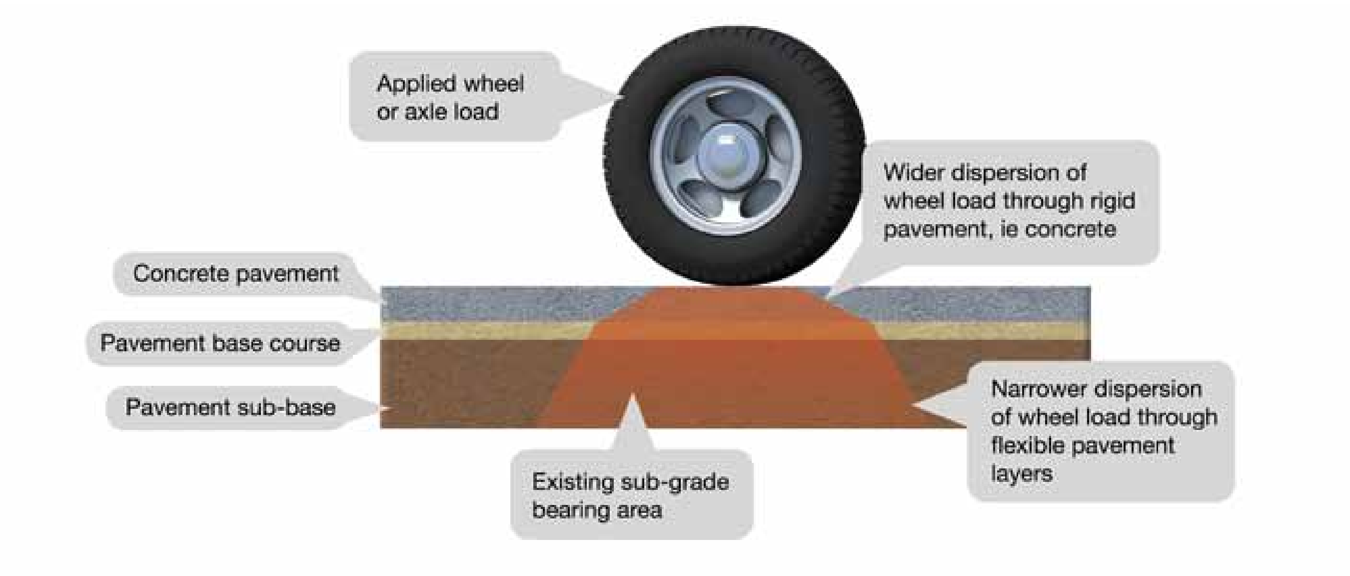


Fig 2.3.3

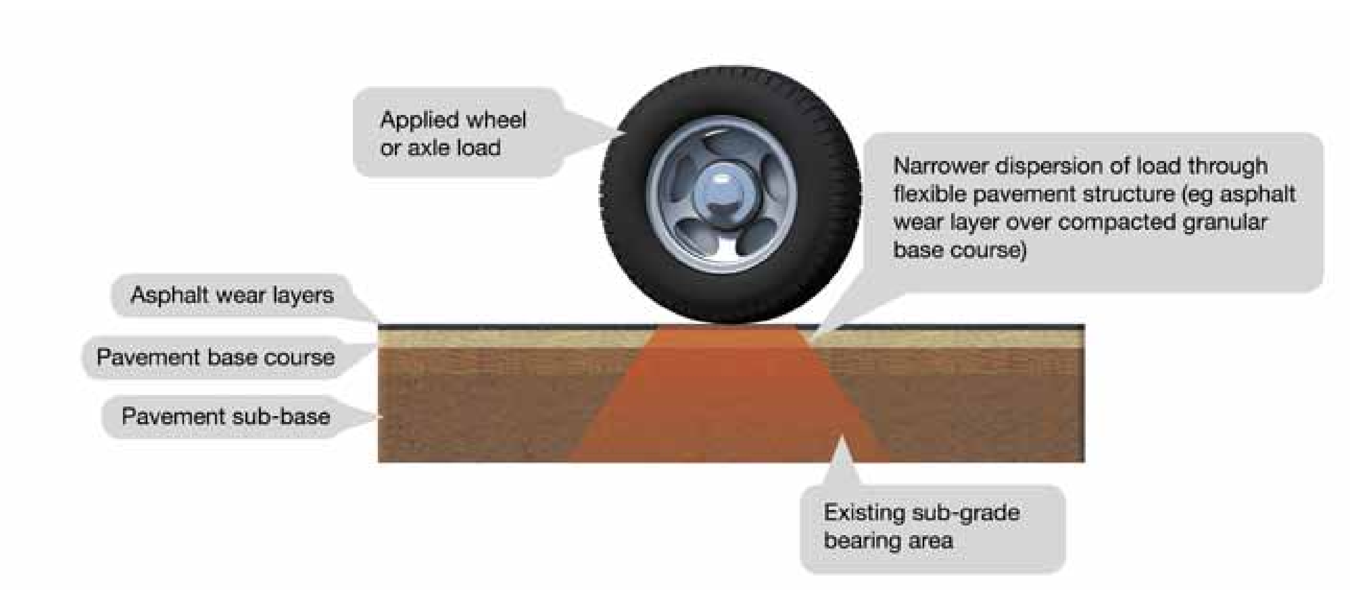


Fig 2.3.4

Traffic loads are dispersed differently through rigid pavement layers, **Fig 2.3.3**, to flexible pavement layers, **Fig 2.3.4**.

Soil structure refers to the arrangement or aggregation of the soil particles. Good soil structure allows for water and air infiltration and movement, besides root growth.

Infiltration rates for soil media in rainwater harvesting treepit designs is critical. Many experts recommend a range of 100mm (4") to 200mm (8") per hour.

Sub grade strength

The subgrade is the soil underneath any pavement structure which bears the load of the pavement and the traffic. Subgrade may comprise naturally occurring earth, previously disturbed soil or fill brought from elsewhere. While subgrade provides the ultimate support for the pavement, structurally it is usually the weakest component in or around a pavement. For a pavement structure to be durable, it must protect the subgrade from deforming and it does this by spreading the load over the subgrade.

Because natural soils vary, the site subgrade characteristics are an important consideration in pavement design for that site. Typically subgrade is composed of clay, silt, sand and gravel, each of which has different particle sizes and chemical properties.

Wheel loads and global standards

Total traffic load on a pavement comprises the magnitude of individual load events such as pedestrians, cars and trucks, and the frequency of events over time. This range of loads is expressed in terms of a common unit of measurement, the standard reference vehicle. Any vehicle can be related to the reference vehicle by its equivalent wheel load (EWL) or equivalent single- axle load (ESAL).

The deterioration of pavement over time is directly related to traffic load expressed as ESAL. When a pavement is designed, it's predicted ESAL is taken into account and its lifetime in years is calculated. Once this time arrives, the pavement is assumed to require some rehabilitation.

Direct load

Pavements in cities must be engineered to withstand static and cyclic loads in accordance with applicable standards. Fully loaded emergency vehicles such as fire trucks must be able to access properties without causing catastrophic pavement failure. Where below ground tree pits are used, they must be capable of supporting applied loads while providing large volumes of uncompacted soil for root growth.

Lateral load

In addition to direct vertical loads pavements are subjected to significant lateral force. Frequent, heavy traffic may cause the road pavement to fail adjacent to a tree pit and unless prevented, the base course may be displaced laterally into the tree pit void space. It is important that engineered space for tree root systems must be capable of withstanding this lateral force.

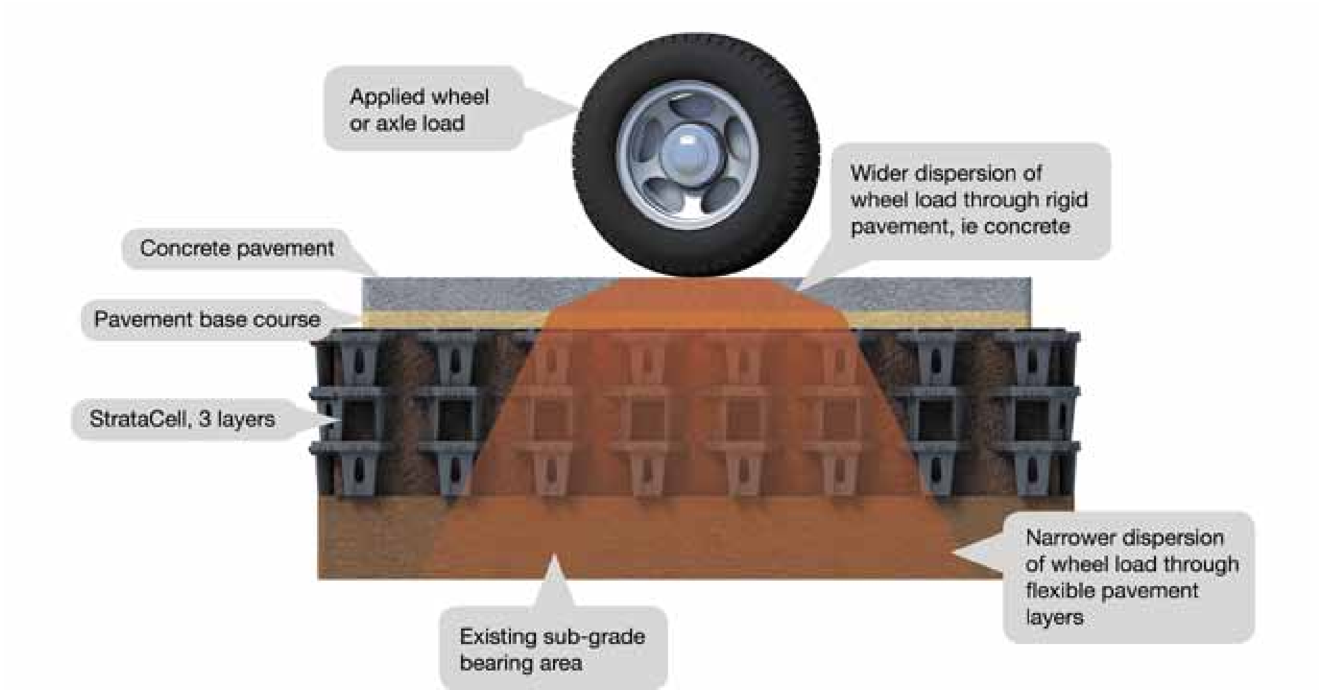


Fig 2.3.5

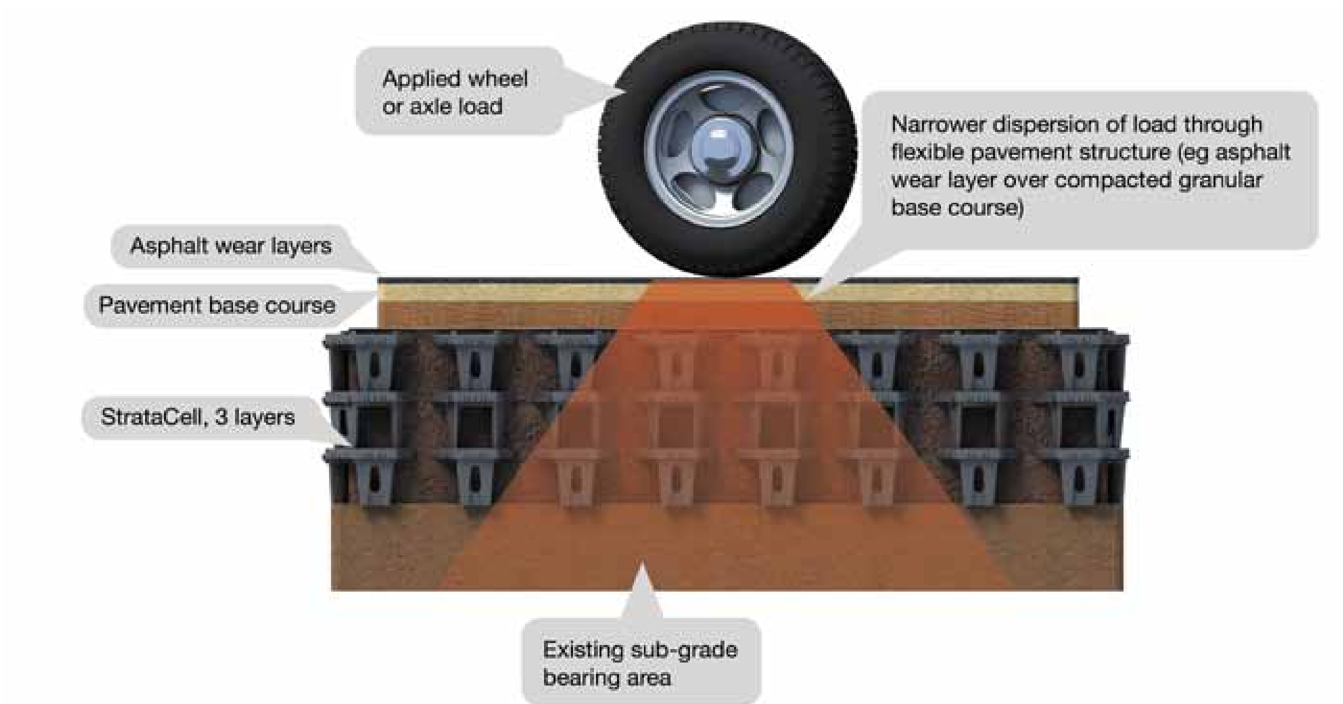


Fig 2.3.6

Interlocking Structural Soil Cells support pavement loads, with pressure being dispersed throughout the matrix in the same manner as engineered base course. Rigid pavements, **Fig 2.3.5**, transfer load over a larger area than flexible pavements, **Fig 2.3.6**.

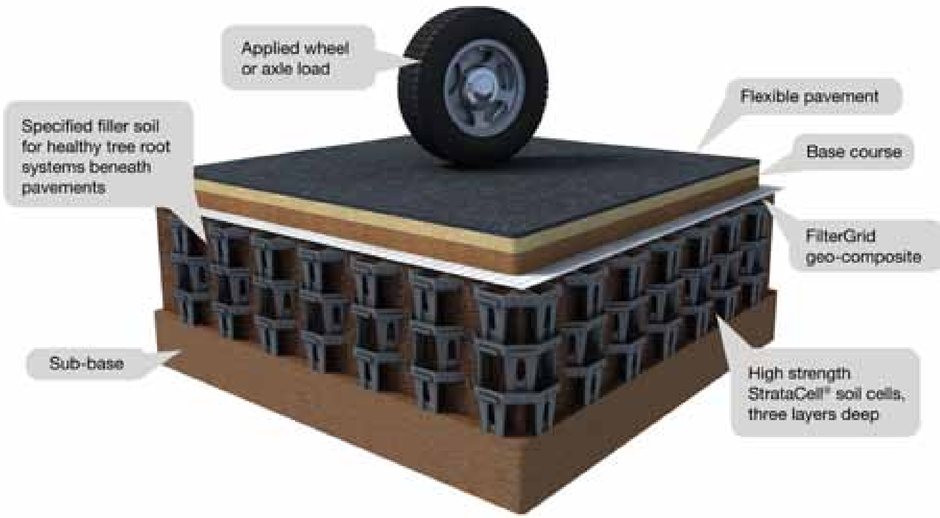


Fig 2.3.7

Compaction destroys soil structure by crushing the pore spaces. Compacted soils must be carefully worked and amended to restore optimal soil structure.

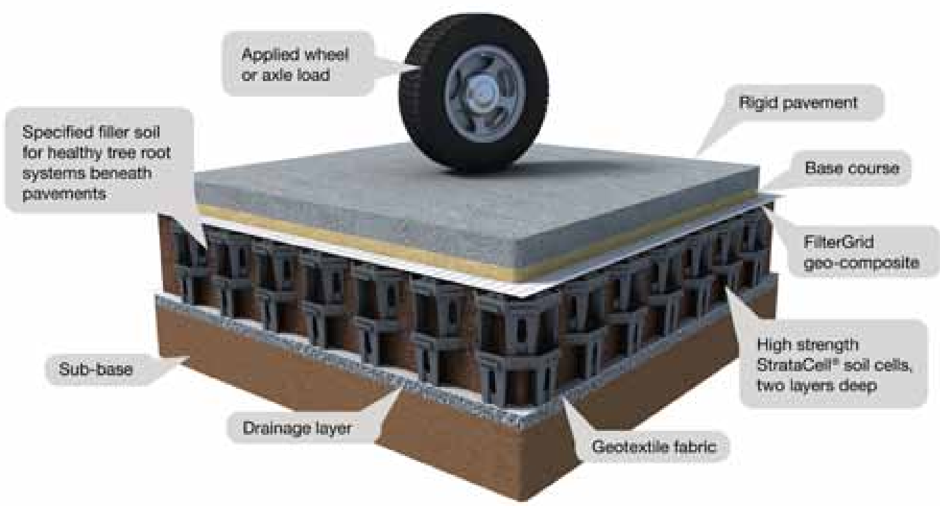


Fig 2.3.8

Approaches to ensuring subgrade strength

Interlocking structural root cells are a highly recommended method to ensure pavements and their subgrades are maintained despite the loads placed on them. These cells have been designed to support enormous vertical loads while providing uncompacted soil for tree roots and enabling tree root systems can be brought closer to the pavement surface.

Structural root cell units lock together to form a monolithic structure with excellent modular strength, both vertically and laterally. An assembled Strata Cell® matrix has been FEA tested to 550kPa vertical load. Engineers have calculated that with only 300mm of granular pavement depth Strata Cell® matrices can support maximum traffic loads.

Interlocking structural soil cells form a fully engineered support for pavement loads while providing 94% void space for soil or bio-retention. **Fig 2.3.7 & 2.3.8**.

Water Harvesting and Strata Cell® Matrix

There are many sound reasons to support the incorporation of Water Sensitive Urban Design principles in structural soil cell treepits beneath pavements.

Indeed, this is a very logical progression that has been extensively trialled in various regions globally. The design concepts for water harvesting treepits are explained in detail in the GreenBlue 'Harvesting Rain Water with Trees' booklet.

Fig 2.3.9 - The structural integrity of Strata Cell matrix provides many new opportunities for both storage and re-use of rainwater, for Low Impact Development.

Large, old trees in cities were often established under completely different growing conditions than today. Old trees have been growing and developing for a long time. Today's pavements and road bases are placed with high compaction levels and very large equipment. These pavements are excellent engineered structures (especially compared to pavement structures of 50 to 100 years ago), and successfully growing healthy trees within these structures requires correctly designed and engineered treepits.

Incorporating Services within Strata Cell® Matrix

Utility services are often found to be in conflict with the requirements of trees in cities. This requirement needs to be considered at design stage, in view of a successful outcome for all parties.

Many services (up to 140mm) can be integrated within the Strata Cell® modules, due to the enlarged spaces between the load bearing columns.

Larger diameter services (up to 180mm diameter) can be accommodated within the StrataDuct service trunk. This superior design allows large services to be isolated from the structural matrix, within an enclosed service trunk, for access without disturbing tree roots or soil.

For services that are over 180mm in diameter, the structural soil cell matrix is segmented to provide sufficient clearance for the utility, and treated as a conventional service trench.

Recycled Content

Fig 2.3.10 - Strata Cell® Gen 5 - 100% recycled polymers.

The Strata Cell® is a very highly engineered module that owes much of its incredible strength to a unique design (subject to numerous patents). So strong is this design, that the base model Strata Cell® (Series 30) has an ultimate strength in excess of 300kPa without relying on any steel bars (subject to corrosion), or glass reinforcement, or virgin resins. This module is 30% stronger than any comparable large soil cell, and is made entirely from recycled Polypropylene. Due to the emphasis GreenBlue places on environmentally sustainable systems, over 400,000 kg of plastic are saved from landfill every year.

The top model Strata Cell® (Series 60) has an ultimate strength of 600kPa, and is manufactured from a unique blend of recycled PP and glass fibre. Capable of withstanding heavy traffic loads, the Series 60 Strata Cell® is the world's strongest large soil cell by a huge margin.

Structural Integrity

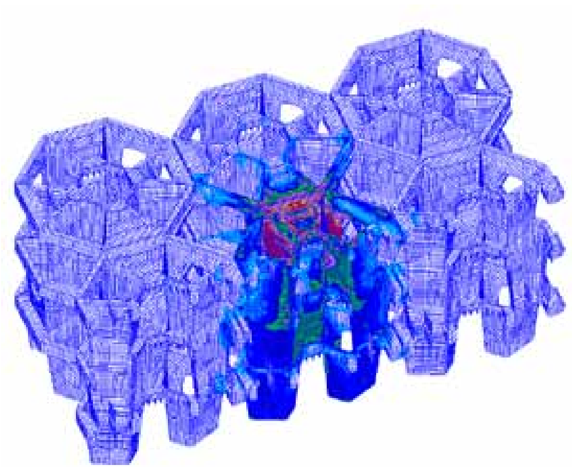


Fig 2.3.11 - Strata Cell® load testing showing even load dispersion through the connected matrix.

Strata Cell® modules are crush tested during manufacture as part of the rigorous quality control standards required by GreenBlue. Whilst FEA (Finite Element Analysis) computer load testing was also conducted during the initial design stages to project the loading capacity laterally and vertically, physical laboratory tests were then used to clarify the cells actual loading capabilities. This physical load testing is part of an ongoing development and research program, and is the only true measure of structural integrity. Strata Cell® modules are made using 100% recycled polypropylene, and have the highest structural integrity of any large soil cell.

Fig 2.3.12 - Physical load testing of the Strata Cell® GenV.

Fatigue Testing

As the world's strongest large soil cell, Strata Cell® has been subjected to extraordinary laboratory tests, including fatigue testing. In one test a university applied a load of 8.6 tonnes to a Strata Cell® tower 10,000 times. The tower was then crushed to measure whether the ultimate load had been diminished by the cyclic loading. The high strength modules had lost no strength, verifying the design strength of this remarkable system.

Energy Use

The use of virgin resins in a product for the Green Building Industry has never been a part of the Strata Cell® development program. Virgin plastics have an unacceptably high level of embodied energy, whereas recycled waste plastic into an engineering grade product starts with a clean sheet as recognized by industry and the Green Building Council.

The development of root cells

Structural root cells were first developed in Britain in 2005 (Generation 1), followed by Generation 2 in 2006. Generation 3 was produced in Australia in 2007 to provide a larger module with greater spaces for root growth.

'StrataCell®' represents the latest generation of root cell and has been developed and patented globally by Citygreen Systems (GreenBlue partner). Strata Cell® builds on the experience gained through trials, projects and collaborations with industry innovators. The main drivers have been the need for lower installation costs, higher strength, reduced transport costs and maintenance of large spaces for root growth. Fig 2.3.13, 2.3.14 & 2.3.15

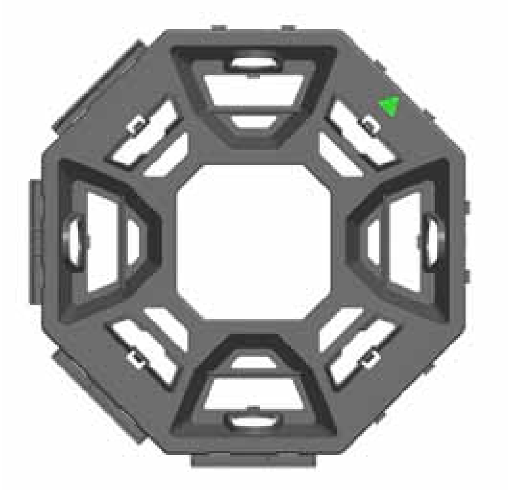


Fig 2.3.13 - Strata Cell® module top

Fig 2.3.14 - Strata Cell® module isometric

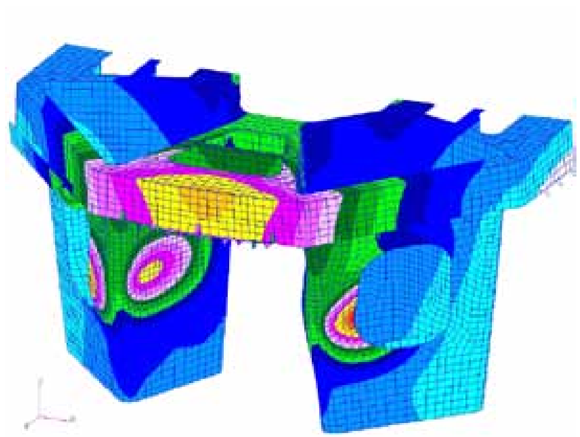


Fig 2.3.15 - Strata Cell® load testing

The root system of a tree may extend up to two to three times the area of the tree canopy.

Design features

The fifth generation root cell provides very generous apertures for root growth without sacrificing the structural integrity of the matrix. Strata Cell® apertures are large enough to permit common conduits, service pipes and aeration systems to be incorporated within the structure.

The open skeletal structure of the Strata Cell® matrix provides an optimal growth zone for tree roots. Due to the advanced engineering design of these modern structural modules, more than 94% of the total volume of the root cell is available for tree root growth. Strata Cell® structural modules are made from 100% recycled polymers.

Assembly

Strata Cell® has been designed to achieve major reductions in installation costs. Units snap together quickly and easily, with labour times being drastically reduced.

Positive and secure connectors are a feature of the Strata Cell® patented design both vertically and laterally. Strata Cell® modules are simple and fast to click together, producing an integrated matrix. **Fig 2.3.16**

Fig 2.3.16 - Assembling High Strength Structural Soil Cells in Scandinavia

Volume reduction for freight

Another unique design feature of the new Strata Cell® module is the significant volume reduction for freight. With increasing scrutiny placed on use of fossil fuels and shipping costs, it was decided that this unit must achieve major volume reductions for shipping. The innovative nesting design is protected by worldwide patents and design registration, as are all other desi features. **Fig 2.1.17 & 2.3.18**

Fig 2.1.18 - Strata Cell® module stacked.

Fig 2.1.17 - Strata Cell modules are designed to minimise freight costs.

STRATA CELL®

Benefits

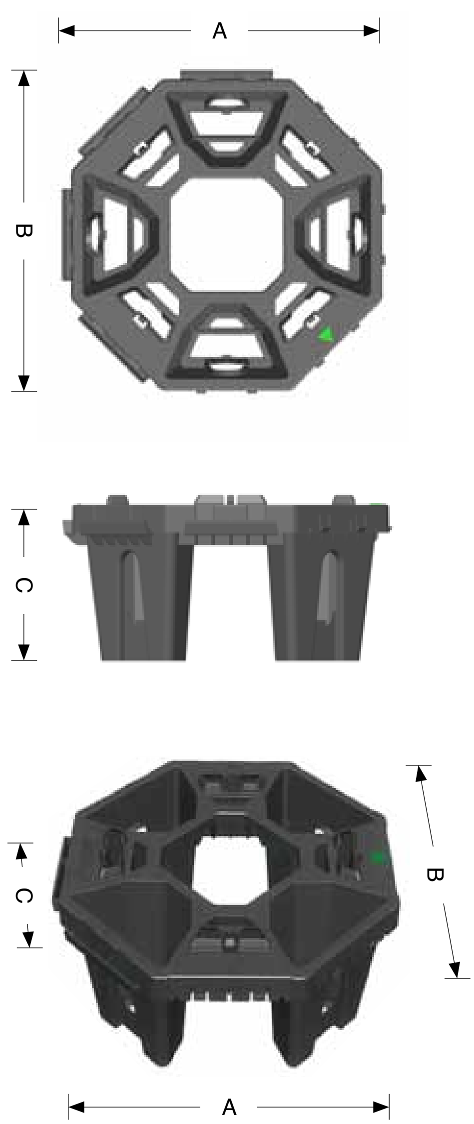
- High Strength
- Fast Installation
- 100% Recycled Polymer
- Laboratory Tested
- Low Shipping Volumes
- LEED Contribution

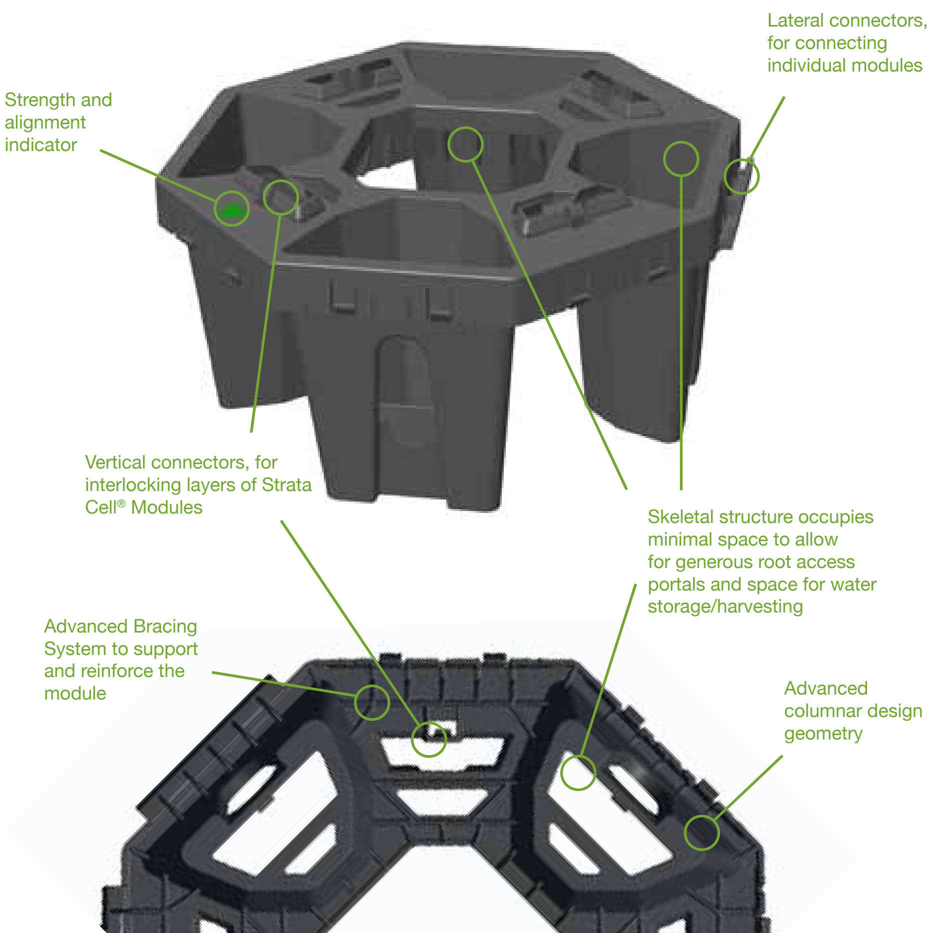
Structural Module for Treepits in Paved Areas

Probably the most critical factor in tree health and longevity, is the provision of enough quality soil for the tree roots. Arborists and allied researchers insist that a healthy tree's root system will extend significantly beyond the 'dripline' or canopy area of the tree, in natural circumstances. The GreenBlue modular StrataCell® system employs advanced design geometry and reinforced copolymers to produce an incredibly robust, skeletal matrix.

This matrix has been tested by Finite Element Analysis, as well as physical Ultimate Load tests at university. These test results have been verified by consulting engineers to provide adequate support for pavement loads. (Consulting engineers are available to assist with pavement design calculations for your project.)

Arborists are pleased with the open space design of Strata Cell® module. Large avenues within the matrix are designed to accommodate structural root systems. Indeed, over 94% of the entire matrix can be filled with friable soil, for the development of large healthy root systems that support beautiful trees for future generations.





Strata Cell® has worldwide patents registered and pending

Strata Cell® modular system is fast to install, and ideal for provision of large soil volumes (94% of total pit volume) beneath paved surfaces.

Continuous, linked soil trenches provide ultimate growth opportunities.

Product Code	Dimension A	Dimension B	Dimension C
SC250-60	508mm	508mm	250mm
SC250-30	508mm	508mm	250mm

Strata Cell® has worldwide patents registered and pending

THE GREENBLUE STORY

GreenBlue was established to provide engineered green building solutions based on sound research into urban sustainability. Our solutions have proved to be current best practice in their field, endorsed by professional organizations around the globe.

The GreenBlue Name

Our name reflects our passion – to help make our cities more sustainable. From our dedication to research and development and hands-on experience in the field has come a firm belief that there are ways of successfully integrating 'green utilities' – trees, soil and water – into urban design to make our cities greener and more liveable.

The GreenBlue Vision

Our company vision embraces a world where sustainable green space is within reach of every person, every day – and natural resources are utilized (not wasted) for the benefit of mankind.

Trees in Cities

One of the key focus areas of GreenBlue is green utilities. Trees as green utilities play a major role in maintaining sustainable ecosystems in our cities and should take precedence in urban planning and design if we, and our generations to come, are to reap the benefits.

Aiming to significantly improve urban planting success and increase urban forest canopy, GreenBlue researched the reasons for premature mortality in urban trees and poor tree growth in urban environments. We identified the key issues, devised solutions and designed practical products and systems. Successfully!

Green Walls

Included in the GreenBlue range of green building products is the European brand of green wall trellis systems – our Green Walls. This innovative range opens up a whole new dimension to your urban landscape designs.

Greening of facades, pergolas and garden spaces is an ecologically sound method of taking your project beyond the ordinary. Greening of compacted urban landscapes and brownfield sites has an ever increasing importance.

Global Partners - Combined Experience

Collaboration with global research and distribution partners over the last two decades has placed GreeBlue systems at the cutting edge of sustainable tree pit solutions for cities. GreenBlue works closely with renowned European organizations such as Greenleaf (United Kingdom, Germany, Ireland, and Spain) and Scandinavian company Milford (Denmark) and is quickly becoming the North American and Australasian market leader in specialist green technology systems.

Local authorities, arboriculturists, landscape architects, civil engineers and other related professionals increasingly collaborate with GreenBlue in implementing current best practice in green technology. As the industry market leader in specialist green building products, we are able to offer the results of 18 years of frontline experience in the field, exhaustive research, product development and field trials. Our support service, unrivalled in the tree planting world, can help you to achieve your vision.

Testing of pavement above and adjacent to structural soil cell treepits. 400 passes on pavement and 200 passes on sidewalk failed to induce any measurable pavement collapse.

Research and Development

Ongoing research and development is a key to the growth of GreenBlue, with knowledge gained in laboratories and field collaboration construction sites being shared with industry partners. As a company, GreenBlue pursues the current boundaries of design relentlessly to bring to the market proven engineered green building systems that provide optimum solutions for urban planners.

Trees with aggressive root systems have been planted in GreenBlue root management and soil cell systems, and excavated for research.

Training and Accreditation

Long term success of engineered green building systems is directly impacted by the quality of installation. Not only is the health of trees and shrubs but also pavement integrity and storm water function in danger of compromise, with potentially dire consequences, if installers are not competent in best practice installation.

For this reason, GreenBlue has developed a unique accredited e-learning program. Installers may complete this comprehensive training course online to gain Arborsystem accreditation. This accreditation status is part of the prerequisite package for product warranty recognition and is further evidence of the dedication of GreenBlue to the Green Building Industry.

Technical Support

GreenBlue strives to provide world class support for designers and installers of the various green building systems available. Complete suites of drawing files in 2D CAD format and PDF are available to designers, free of charge.

Detailed product and installation specifications are available for inclusion in project designs, many of which are fully editable. GreenBlue consultants are also able to obtain independent engineering advice on behalf of clients, utilizing qualified engineers with key experience in the use of GreenBiue green building systems.

GreenBlue invests in physical, laboratory testing - for verified structural data, and development of cutting edge green building systems.

GreenBlue
INFRASTRUCTURE SOLUTIONS

GREEN ACCREDITATION—

EARN LEED POINTS BY USING GREENBLUE STRATACELL® MODULES

Leadership in Energy and Environmental Design (LEED) is an internationally recognized green building certification system, providing third-party verification that a building or community has been designed and built using strategies intended to improve performance. Metrics used include the following: energy savings, water efficiency, CO2 emissions reduction, improved indoor/outdoor environmental quality, and stewardship of resources and sensitivity to their impacts.

Developed by the U.S. Green Building Council (USGBC), LEED is intended to provide building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions.

Widely accepted in North America and Canada, LEED uses a points-based system to guide design and measure performance. The higher the number of points awarded to a building or community, the higher its assessed sustainability. Not only is this expected to increase asset value and reduce operating costs, in many cities, LEED ratings qualify for tax rebates, zoning allowances and other incentives.

Using GreenBlue Strata Cell® Modules can help clients earn additional points in the categories of: creating sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality, neighbourhood pattern and design and green infrastructure and buildings.

If your building project is a candidate for LEED credits, review our LEED Rating System Checklist. Your project is a viable candidate for certification if it meets all prerequisites and can achieve the minimum number of points necessary to earn the credits.

ArborSystem

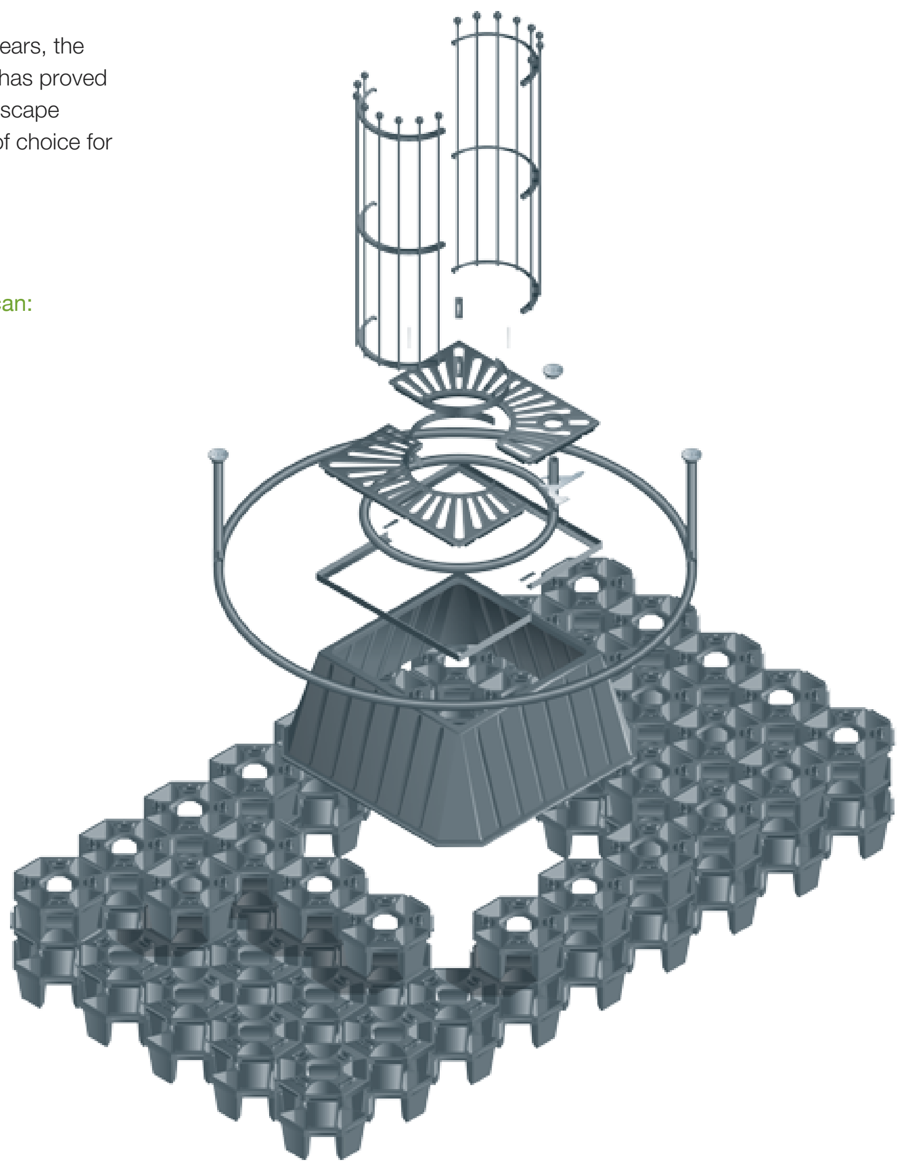
The definitive urban tree pit package

The GreenBlue ArborSystem brings together the key elements of successful tree pit design and simplifies the design and installation process for specifiers and installers. By utilizing our Arborsystem CAD library (within the resource section of the GreenBlue website), landscape professionals can combine root management, structural soil components, aeration, and irrigation - in a single package – and then choose an appropriate above ground surface grille and vertical guard to match their project.

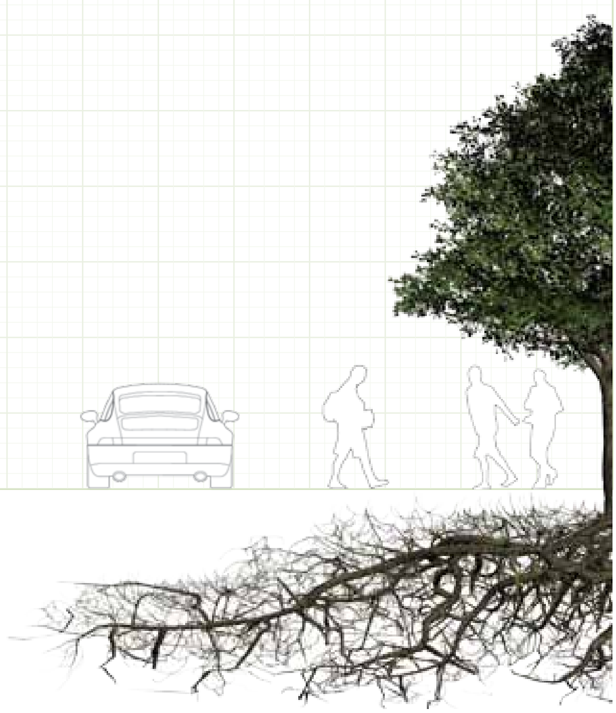
Since its inception and development over recent years, the ArborSystem integrated tree pit product package has proved itself in many demanding locations. For many landscape specifiers, ArborSystem has become the system of choice for integrating trees into the urban environment.

By utilizing ArborSystem, landscape designers can:

- **Ensure product compatibility**
- **Drastically reduce time spent on specifying, quoting and ordering**
- **Adapt a system to suit differing location and budget constraints**
- **Demonstrate to clients a professional long term approach to tree planning and management issues**
- **Benefit from our onsite support service for peace of mind.**



Sketch Grid



Notes

greenblue.com

Global Offices

Head Office - North America
GreenBlue Infrastructure Solutions
71 Bysham Park Drive
Woodstock, ON N4T 1P1
Sales & Service: 1 866 282 2743
greenblue.com

Also Represented in

United Kingdom
Australia
Germany
Ireland
France
Spain
Poland
New Zealand
Scandinavia