Growing Condition Improvements for Streetscape Trees

Phillip K, Kevin N, Carlos P, and Ning Z

Engineering Professionalism

4/28/2014

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Executive Summary

The University of Texas at Austin Civil Engineering Professionalism class required students to work on a real life project by working with clients. Our group had the chance to work with the Urban Forestry Program from the Parks and Recreation Department with the City of Austin. The objective of our project is to study and design options to improve the quality of growing conditions for streetscape trees in the Austin downtown environment, with the primary focus in soil volume. Site investigation was done at the beginning of the semester to take measurement of the spacing between the trees and curbs, trees to tress and tree well sizes.

Our preliminary research focused on three sets of criteria, feasibility, durability and cost. More Information was retrieved by attended the Technical Meeting for Street Trees and Soil Volume including the Street Tree Research presentation by Dr. Tom Smiley from South Carolina, Tree Benefits presentation by Patrick Brewer from City of Austin and Streetscape Project Installing by Randy Harvey from City of Austin. Over the data that we retrieved from our research, we noticed that the bigger the canopy area of the tree is, the more soil volume is required. Three tree species were taking into consideration, cedar elm, big tooth maple and red oaks; according to our research, we have determined that the red oak requires the least amount of soil volume since it has the smallest canopy area. Three soil additives were considered in order to have an efficient soil system that will save money in the long run. Both acrylic polymer and bentonite are not ideal choices as an underground

+ soil for tree roots due to that they have a high tendency to expand and crack the side walk and upper surface pavement of the street, however, Biochar is the most ideal choice as a soil additive due to its ability to attract and retain water in order to keep the nutrient for the root system as well as required less watering. Therefore, the ideal choice is the Texas red oak with the use of Silva Cells in a three stack high and use Biochar in a connected soil system outlined with Bio Barrier.

Introduction

The University of Texas at Austin Civil Engineering Professionalism class required students to work on a real life project by working with clients from companies. Our group had the chance to work with the Urban Forestry Program, Parks and Recreation Department with City of Austin. The objective of our project is to study and design options to improve the quality of growing conditions for streetscape trees in the downtown environment. Site investigation was done at the beginning of the semester to take measurement of the spacing between the trees and curbs, trees to tress and tree well sizes. More Information was obtained from the Technical Meeting for Street Trees and Soil Volume and outside research such as Street Tree Research by Dr. Tom Smiley from South Carolina, Tree Benefits by Patrick Brewer from City of Austin and Streetscape Project Installing by Randy Harvey from City of Austin. Trees affect several aspects of the community's daily impact and are important that the city provides healthy on long living trees for the future.

Scope of Work

The purpose of this project is to study and design options to improve the quality of growing conditions for streetscape trees in the downtown environment.

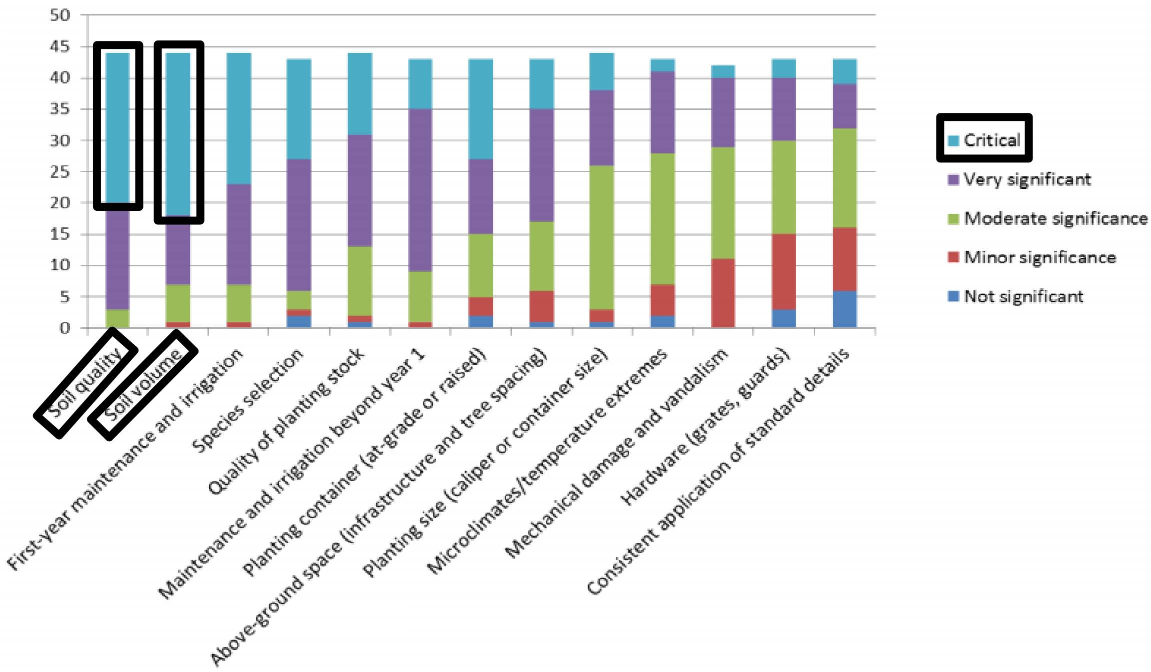


Figure 1: Survey of "Most significant impacts to growing conditions of streetscape trees" by Austin City Council members and subject matter experts, forty-four participants.

As seen in Figure 1 above, the major concerns with the lifetime expectancy of trees in downtown Austin are predominantly soil quality and soil volume, which is the scope of this project.

Study Area

The scope of the project deals specifically with the downtown area. However, downtown Austin is not a well-defined area and it encompasses a large and expansive area. To help with this research, a study area was created.

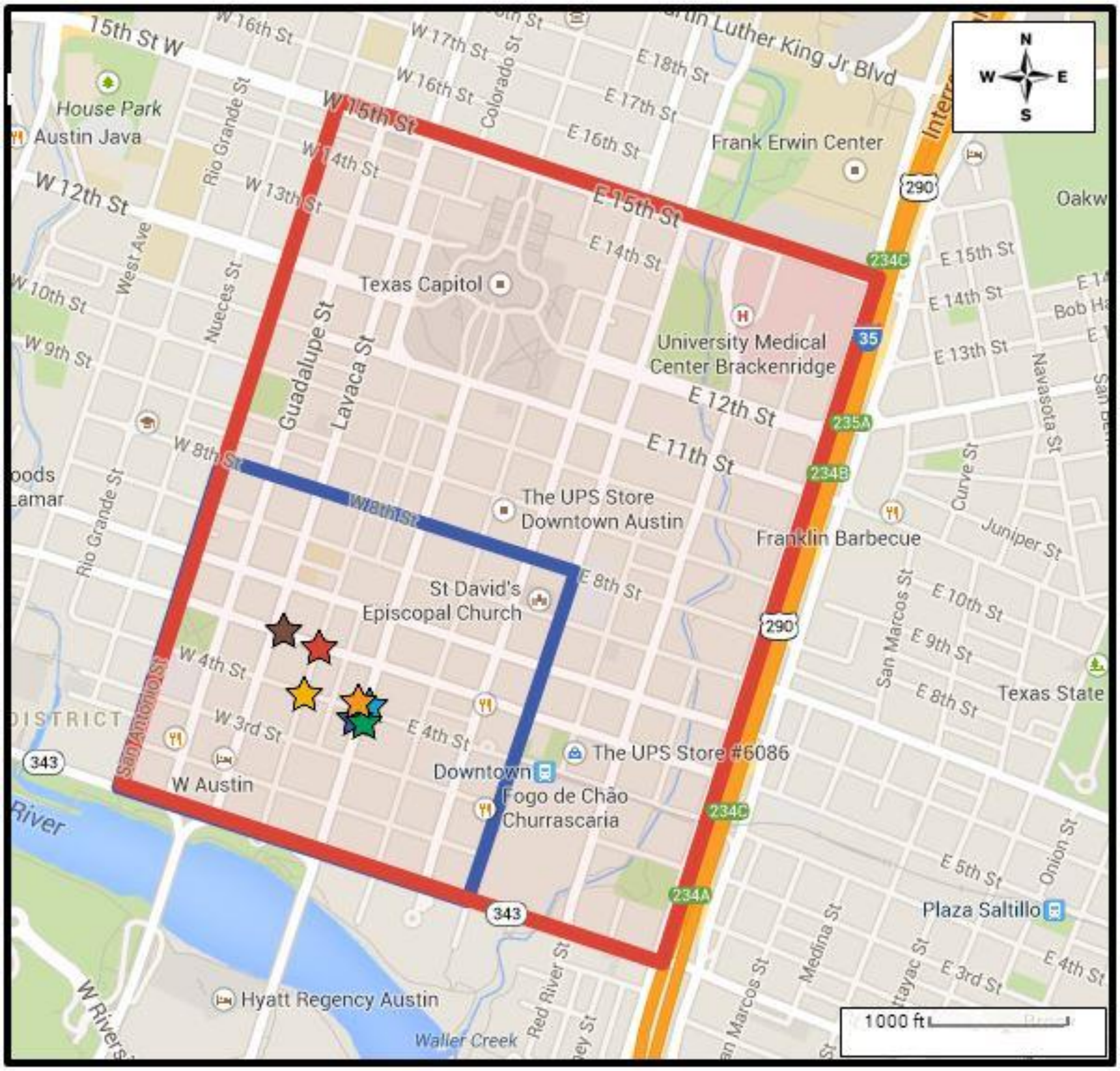


Figure 2: Downtown Austin (red outline) and the Study Area (blue outline)

This study are provided us with many different types of trees as well as many different ways of planting those trees. Those specific locations that were surveyed are shown as colored stars on the map (Figure) above. One thing we noted was that no tree was the same. The way the trees were planted, as well as the distances from things such as the curb, other trees, and utilities all varied. This is an issue that we have looked into solving and plan on creating a uniform and standard planting method across downtown. Our team has prepared an interactive map that can shows these locations as well as measurements and pictures of the differing planting conditions.

Problem Description

Soil Quality

With soil quality being one of the major concerns regarding streetscape trees in downtown Austin, differing soil systems were analyzed to determine optimal soil quality conditions. Suspended, gravel, stalite, and compacted soil systems were researched to define which would provide the optimal amount of soil quality. Figures 3 and 4 below show data that compared the four soil systems against one another.

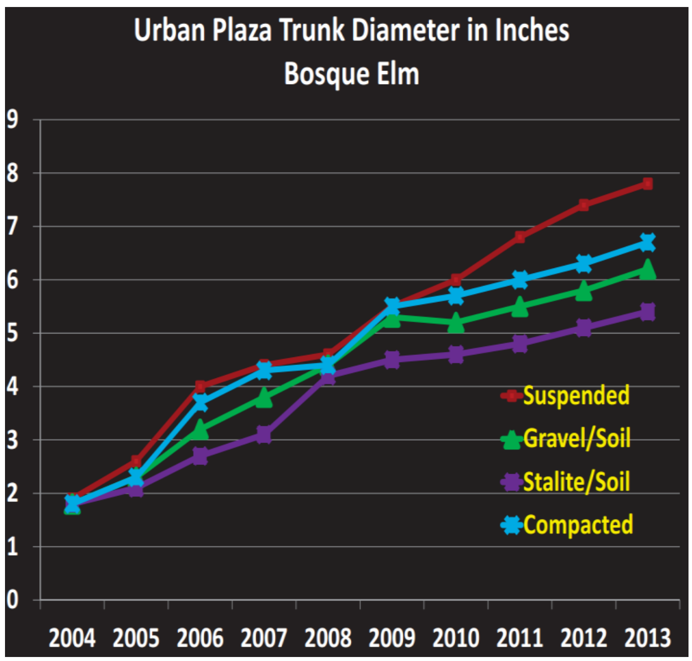


Figure 3: Tree Trunk Diameter of Identical Trees vs. Time

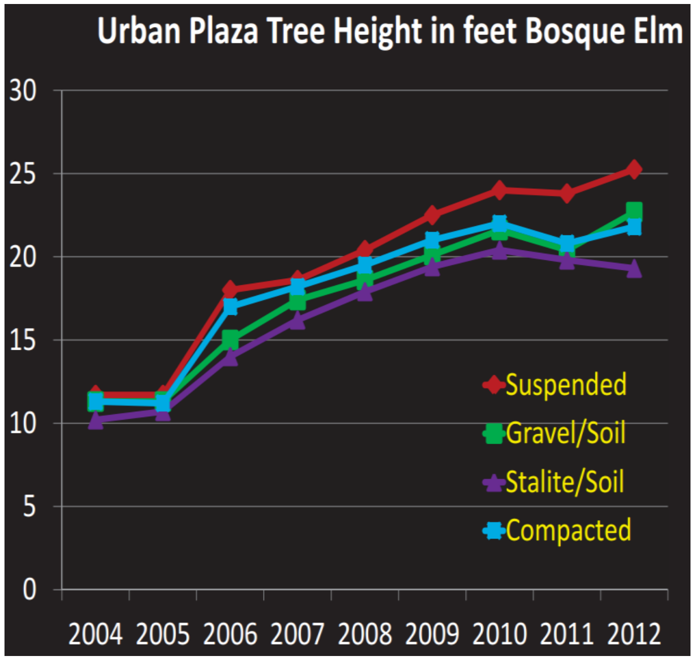


Figure 4: Tree Height of Identical Trees vs. Time

As one can see from the figures above, suspended soil systems provide optimal growing conditions when compared to the other three soil systems. This is beneficial information when regarding the streetscape trees in downtown Austin considering how the existing soil systems are compacted.

Soil Volume

The other main concern for growing conditions is soil volume. Currently, most of the trees in downtown have small tree pits that are not capable of providing adequate soil volume for unhindered growth. Inadequate soil volume is one of the major factors in premature mortality of trees in urban areas (Lindsey & Bassuk, 1991). Along with the small soil volume, these small tree pits do not hold sufficient water and prevent adequate root growth. But how much soil is adequate? Different trees require different amounts of soil and space to grow. Even then, all trees grow differently and are unique. To answer this question, different research on tree growth were compiled and averaged.

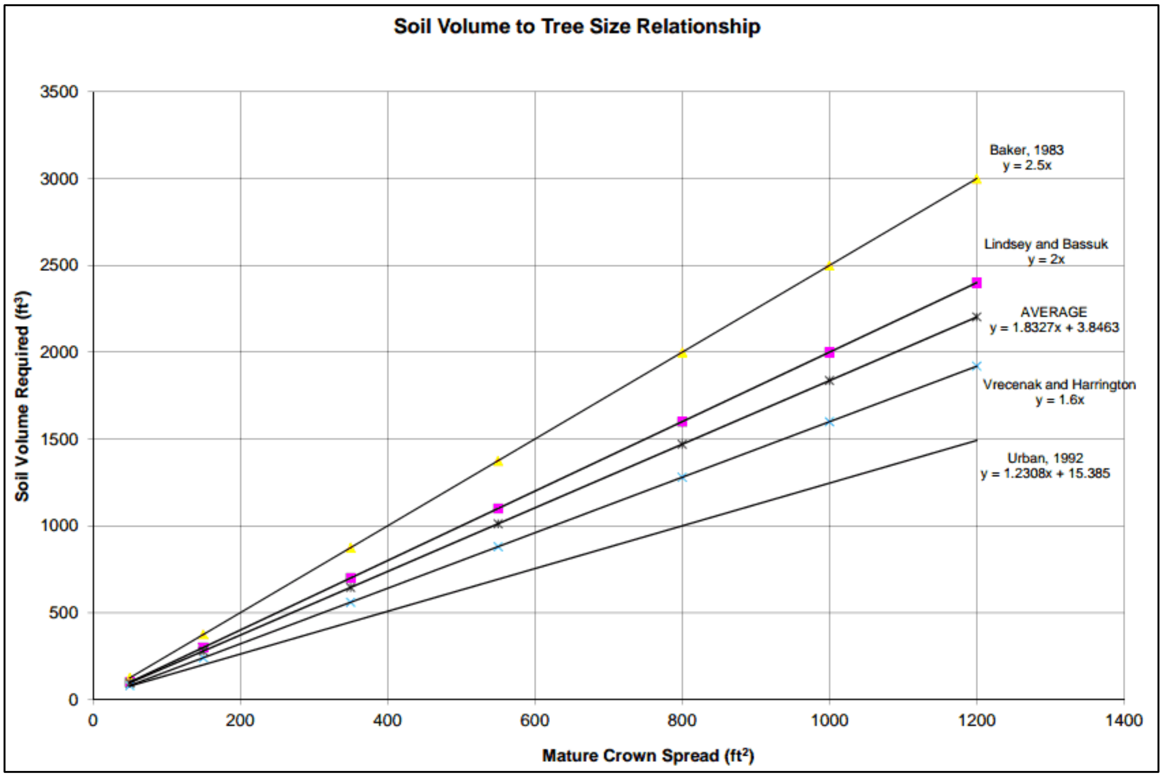


Figure 5: Required Soil Volume for Different Mature Crown Spread

As seen by Figure 5 above, apart from the different research, there is a direct relationship between the required soil volume and the mature crown spread of a tree. This means that given the mature size of a tree, the required soil volume can be estimated and provided for adequate growth.

The city of Austin created a list of recommended trees that should be considered when analyzing soil volume. This list included the soil volume requirements as well as the mature size for the Cedar Elm, Big Tooth Maple, and Red Oak. Table 1 below shows this data that was found from two different research studies.

Table 1: Mature Canopy Size and Expected Soil Volume Requirement of Cedar Elm, Big Tooth Maple, and Red Oak

Common Name	Canopy Area (ft^2) – ECM	Canopy Area (ft^2) – TAMU	Expected Soil Volume Requirement	Soil Volume Required (ft^3)
Cedar Elm	707	3,848	Very Large	885 – 4752
Big Tooth Maple	491	1,257	Large	620 – 1,562
Red Oak	491	N/A	Medium	620

Research

Silva Cell

With the understanding that suspended soil systems provide optimal growing conditions for streetscape trees, research was done to determine how a suspended soil system can be constructed. The answer to this is a Silva cell modular framework. "The Silva Cell is a modular suspended pavement system that uses soil volumes to support large tree growth. Each Silva Cell is composed of a frame and a deck that holds 10 cubic feet of soil (Silva Cell)." The configuration on the frame and deck can be seen in figure 5 below.

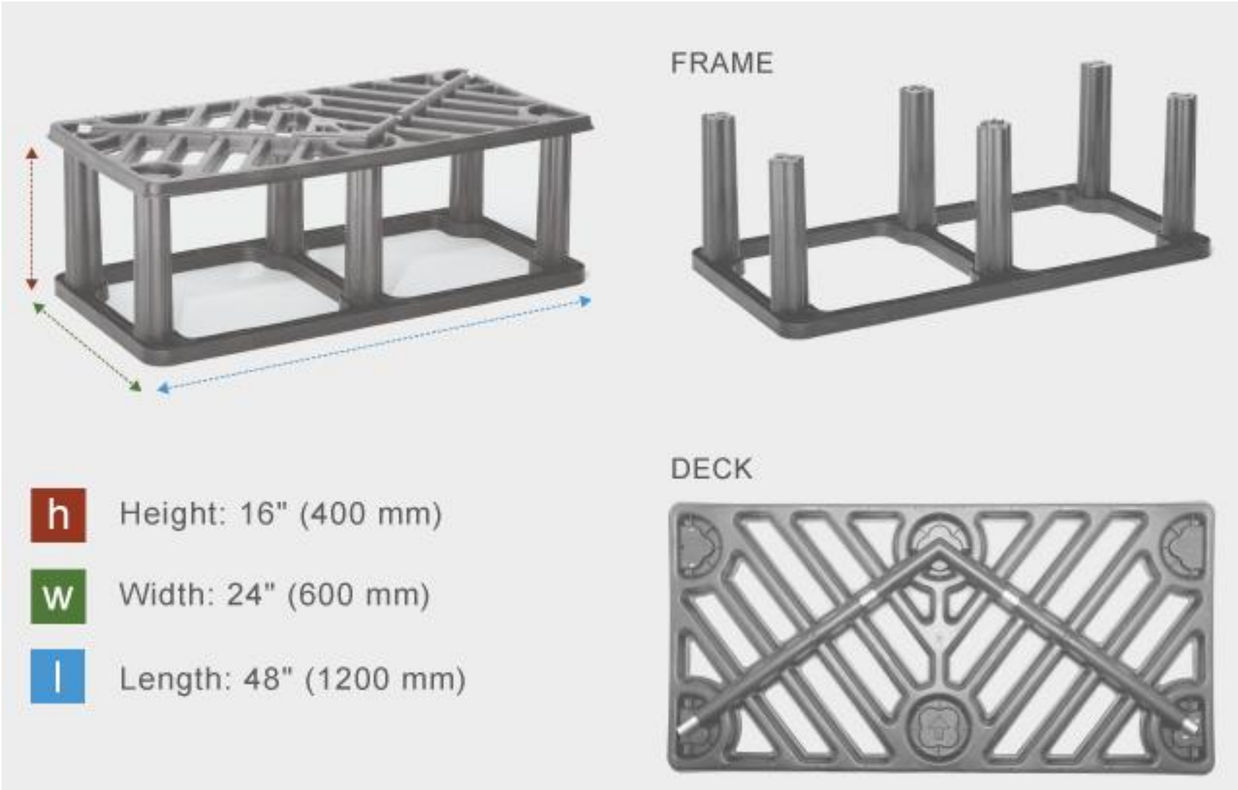
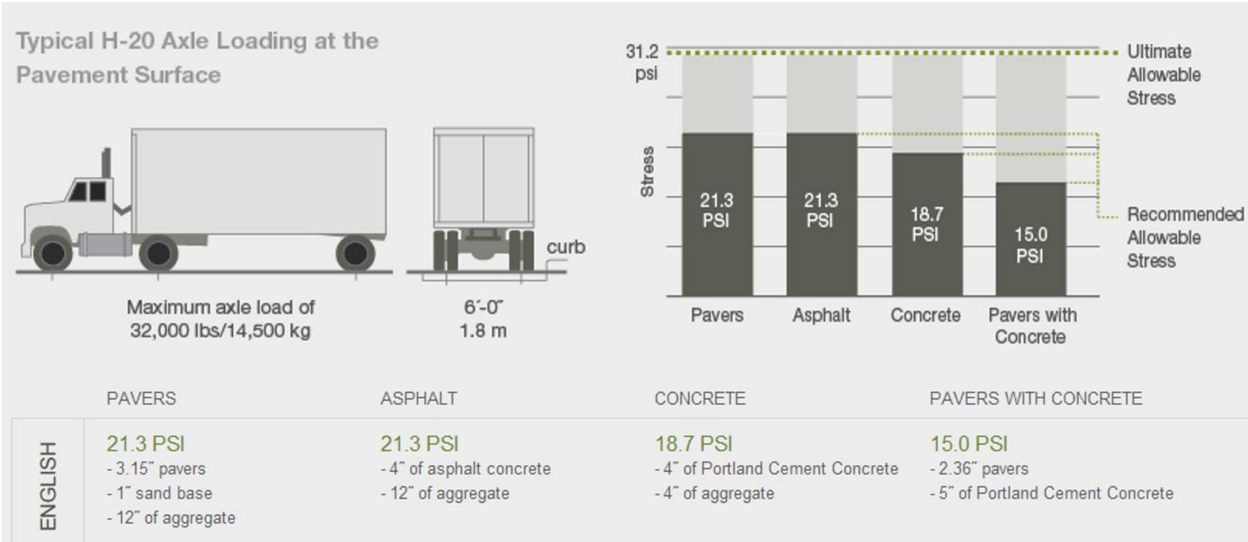


Figure 6: Frame and Deck Configuration of Silva Cell (Silva Cell Tree and Stormwater Management System, 2014)

"Each Silva Cell can be stacked, one, two, or three high before they are topped with a deck to create maximum containment area for lightly compacted loam soil. Silva Cells can be spread laterally as wide as necessary. Each unit is about 92% void, making it easy to accommodate utilities (Silva Cell)."

One concern when considering the implementation of Silva Cells is, will this system will be able to handle the loads that will be applied to it under normal traffic. It was found that a Silva Cell modular framework will be able to handle these load, this can be seen in figure 6 below.



As shown in the figure above, the ultimate allowable stress for this framework is 31.2 psi, which includes

Figure 7: Allowable Loads for Silva Cell Modular Framework

a safety factor. This stress is well above the maximum loads that will be applied by normal traffic through the downtown area. The load is transferred from the above pavement to the Silva Cells uniformly as the pavement is laid directly on top of the flush Silva Cell layer, which is placed above a compacted soil layer to ensure maximum support.

The cost of using a Silva Cell system is another concern that arises when informing about the benefits of installing such a system. The table below shows a representation of the long-term cost advantages of using a Silva Cell based system.

Table 2: Urban Tree Lifecycle Costs and Benefits for a 50 Year Study Period, Based on Typical Costs and Benefits for Minneapolis, MN

	Tree without Silva Cells: Estimated Lifespan 13 years	**Note for Tree without Silva Cells**	**Tree with Silva cells: Estimated Lifespan 50+ Years**	**Notes for Tree with Silva Cells**
Installation Costs	$4,000	Estimated at $1,000 per tree, installed 4 times over a 50 year study period	$14,000	Estimated at $14,000 per tree, installed 1 time over a 50 year study period
Total Benefits	$2,717.66	Includes savings from reduced building energy costs, stormwater interception, increased property values, and the net value of carbon sequestration in the tree	$41,769	Includes savings from reduced building energy costs, stormwater interception, increased property values, and the net value of carbon sequestration in the tree, bioretention, and stormwater utility fee credit.
Total Maintenance Costs	$1,211.95	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs, and administration costs.	$2,341.75	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs,administration costs, and bioretention maintenance
Removal Costs	$600	Estimated at $200 per tree, 3 times over a 50 year study period	$0	Removal Costs
Net Lifecycle Cost	**$3,094.29**		$ **- 25,427.25**	

By providing the proper soil quality, the trees can grow large enough to be able to provide services that over time end up saving more money than the initial cost to install the Silva Cell system. This is because the value of mature urban vegetation actually appreciates over time.

Root Barriers

Additional research was done that analyzed different types of root barriers that would further provide optimal soil quality as well as protect the surrounding utilities. The two different type of root barriers that were analyzed were a “typical root barrier” and a “BioBarrier.”

Typical Root Barrier

This root barrier is composed of a solid, non-permeable recycled plastic that protects surrounding hardscapes by providing a physical wall between the roots and utilities. Two different applications are possible when using this root barrier, which are shown in figure 7 below.

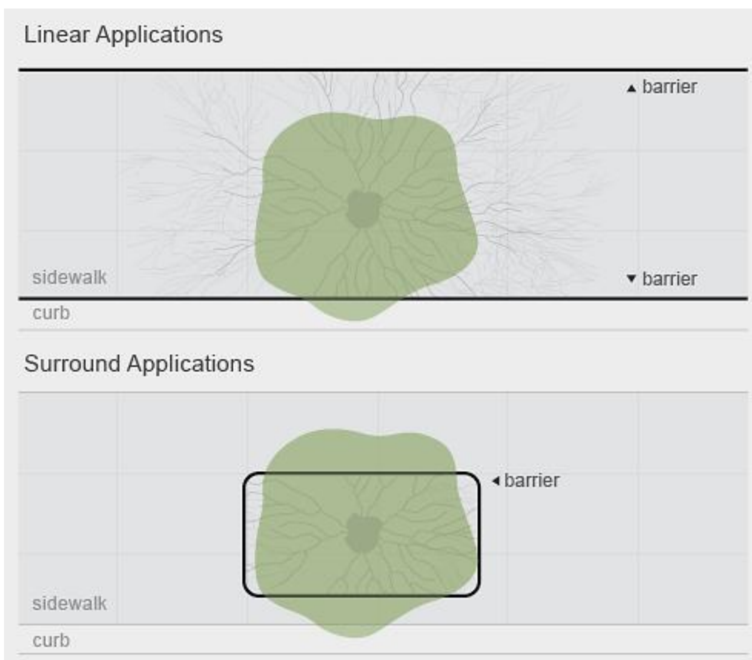


Figure 8: Two Applications of a Typical Root Barrier

This typical root barrier comes in four different sizes with corresponding costs, as shown in figure 8 below.

Figure 9: Size and Associated Costs of a Typical Root Barrier

BioBarrier

A BioBarrier is composed of a standard drainage fabric that allows water and nutrients to pass through while preventing root tip cell division by slowly releasing Triflrualin, a herbicide, at its nodules. This is beneficial as it allows surrounding soil nutrients to enter the root system, promoting growth, while still protecting the surrounding utilities. Unfortunately this product would need to be replaced every 15 years as the amount of Triflrualin is limited. The associated cost of this BioBarrier is shown in the figure below.

Figure 10: Associated Cost of a BioBarrier System

Soil Additives

There are three types of soil additives that we were asked to research for the Great Streets Project. The purpose of these additives is to provide the trees with essential nutrients and water so that they may grow and require less maintenance throughout their life. The soil additives are bio-char, granular acrylic polymers, and bentonite.

Biochar, which is a product of smoldering agricultural waste, can be used to increase soil fertility. This is because it is a stable solid which is high in carbon content. Additionally, it can improve water quality by reducing soil acidity and minimizing irrigation required. These are results of biochar's ability to attract and retain water. Chemically, the structure is porous and has a high surface area.

Moreover, nutrient leaching is mitigated and there is less of a need for fertilizer. Emissions from biomass can also be cut down. Biochar is able to hold carbon for extended periods of time. As mentioned before, this results in increased fertility of the soil, which improves crop yield. This process in turn helps itself; by producing more crops, the CO_2 in the atmosphere is more readily consumed. Methane is also a greenhouse gas that can be combatted by biochar; it is able to naturally decompose it.

Bio char was one of the top choices that we considered.

The second additive is granular acrylic polymer that has a high water absorption capacity and will help to reduce the frequency of irrigation. The major concern with these polymers is that they expand to many times its original size causing swelling of the soils and potential cracking of sidewalks.

Last was bentonite, similar to the acyclic polymer, it has a really high water absorption capacity and will swell into a much larger size than its original once it comes in contact with water.

Both acrylic polymer and bentonite are not the ideal choices as an underground soil additives for tree roots due to that they have a high tendency to expand n crack the sidewalk and upper surface pavement of the street.

Conclusion

After the research was compiled and everything was taken into consideration, an ideal solution was found and is as follows:

- Silva cells are approximately 16” high. Stacked three high, this gives a height of about 48”
- Averaging data from the study area shows available soil volume of 640-670 ft^3 per tree
- Because of these soil limitations, regulations, and the dimensions and limitations of the Silva cell, we recommend the Texas Red Oak with the use of Silva Cells and Biochar in a connected soil system outlined with BioBarrier.
- This system will be 8’ wide, 4’ deep and measure 22’ long (O.C.) between trees and 10’ from trees in the corners of the system

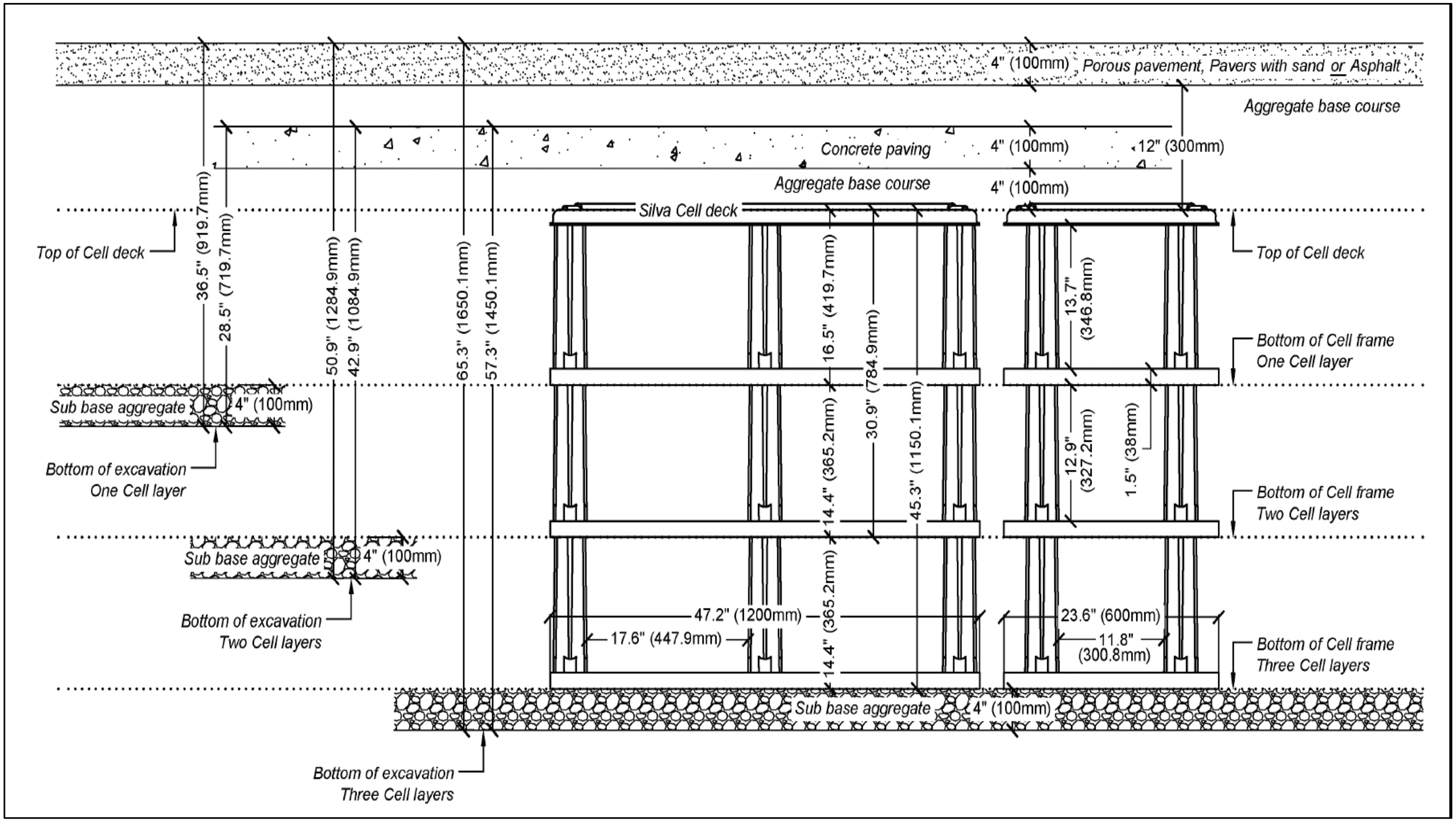


Figure 11: Cross Section View of Silva Cell Modular Framework (Silva Cell System Layout Instructions, 2014)

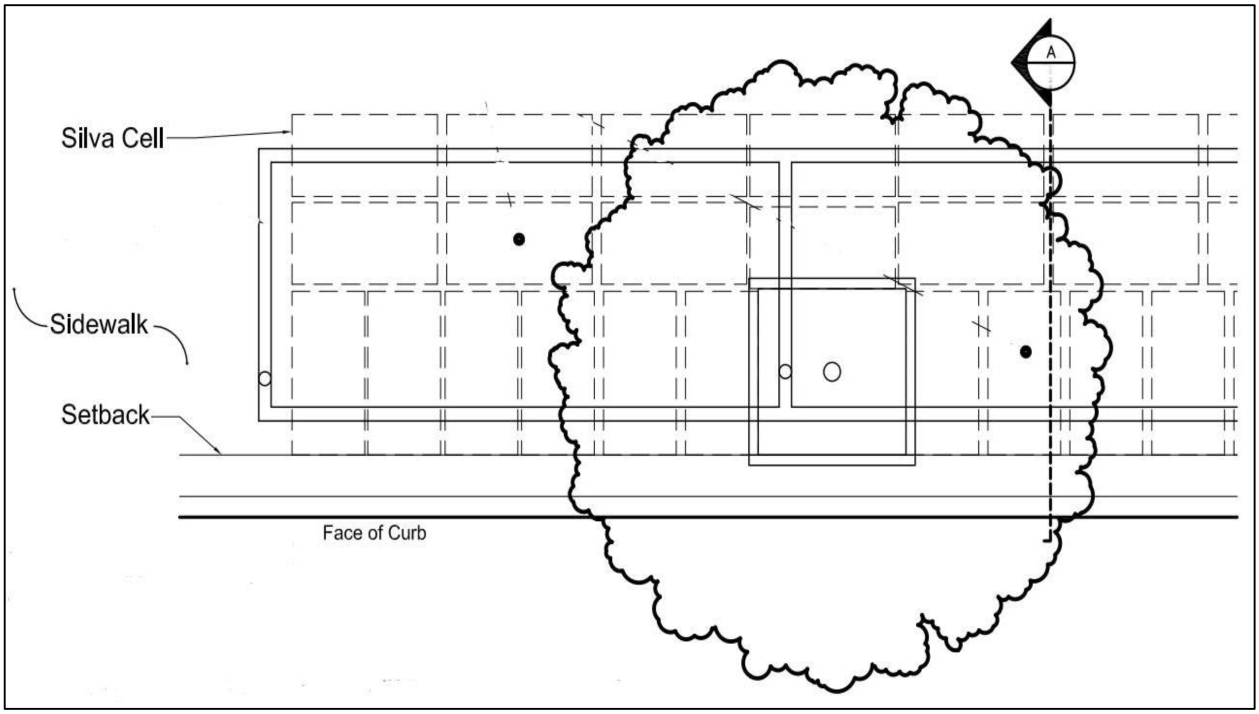


Figure 12: Top Down View of Silva Cell Modular Framework

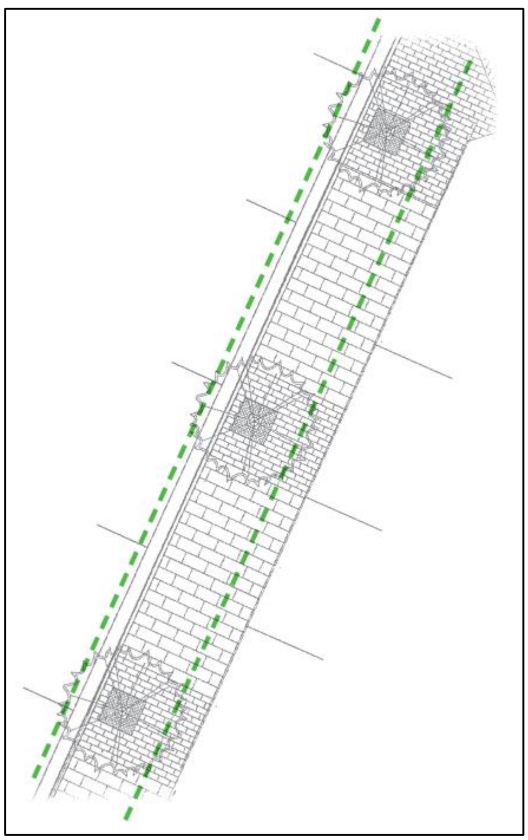


Figure 13: Top View of Connected Tree System (Calculating Target Soil Volumes, 2012)

- In other locations where more space is available (18' trench width), Big Tooth Maple trees can be planted
- Cedar Elm is not recommended given its excessive size and demand for soil volume

By tackling all these issues such as soil volume, soil nutrition, and soil barriers we expect to provide trees with adequate resources to live for the planned lives.

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