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STREET TREES – CURRENT PROBLEMS AND TECHNOLOGIES FOR CONSTRUCTION AND PLANTING

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Abstract

Reducing green areas in large urban areas is a precondition for the growing role of street landscaping. Especially in central urban areas with high building density, trees on the street most often remain the only tall vegetation at the natural terrain level.

A number of studies on the development of street trees over the last few decades in many European cities have shown that their condition is getting worse and their life span is far from their usual potential.

The purpose of the study is to pin down the most important problems of street landscaping and the technologuies used in foreign practices for overcoming the latter. Promoting them in Bulgaria would allow the introduction and respectively the establishment and maintenance of long-lasting street trees in large urban areas.

The study is based mainly on information from literary sources as well as on the survey of products offered by specialized foreign companies primarily for the purposes of street landscaping.

Keywords: street landscaping, street trees, urban trees.

INTRODUCTION

The tendency of reducing green areas in the large cities and urban areas requires street space to be increasingly used for landscaping. With the possibilities regulated by normative documents in our country for achieving the necessary percentage of greenery through roof landscaping, the street trees would remain the only high vegetation at a terrain level in the central urban areas.

Street trees are a vital urban element that can transform the city's streets and provide numerous environmental, aesthetic, cultural and economic benefits. In the long term, they create a "sense of place" and enhance the public domain. Trees can transform a street and create definition within a street. They can be just as important as the built forms in many locations. (City of Sydney Street Tree Master Plan, 2011)

There is no doubt that the role of street trees will become even greater in the future. However, many author's studies about street landscaping show that the integration of trees into urban space is not so painless for them.

The traditional planting technologies used in the past, which are still the only ones applied in our country, are not suitable for the creation of long-lasting street plantings under the conditions of a large urban environment.

Researches that have already been carried out show that the life of trees in cities is estimated to be about 50% of the potential for the species, and for the street trees - only 25% (Roloff, 2013). Urban trees often express reduced vitality and have a lower life expectancy compared to trees in more favorable growth conditions (Balder et al. 1997).

Premature aging and dying are explained by the problems of the street as a place for growing vegetation. According to Mahler (1993), Roloff gives an example of street trees in Berlin that reach at the maximum age of 60 years (Roloff, 2008).

The purpose of this article is to pin down important current problems in street landscaping and after exploring modern foreign construction and planting technologies, to give recommendations on their future application in our country.

The report about street landscaping issues is based on literary sources and own observations. Modern technologies for building street landscaping have been researched through investigating products that are offered by specialized foreign firms.

CURRENT PROBLEMS IN STREET LANDSCAPING

When it comes to the topic "Street landscaping" it is clear that the problem manifests in two directions. On the one hand, facts and logic show, that the streetscape is a problematic location for trees and on the other hand that planting trees

on the street creates problems for underground infrastructure, pavements and, in the absence of adequate care, jeopardizes the safety of pedestrian and transport traffic.

The street as a place for growing trees, as well as all the other green areas in urban territories, is an artificial one and has nothing to do with the trees' natural habitat. That is why it is qualified as extreme, and the main reasons for this are:

- *Limited space for root system development*

Even when complied with the statutory requirements for the distances of the ornamental vegetation from conduits, facilities and buildings the required space for the trees concur with the space where the elements of the underground infrastructure are, and the recommended FLL (2010) 12 m³ space with soil per tree are almost never achieved (Streckenbach, 2012a). Modern technologies for the construction of water and sewage pipelines, gas pipelines, etc., street pavements, and the used materials, create unsuitable conditions for the street trees' root system;

- *Unfavourable soil conditions outside the planting site of the trees*

As a result of construction and repair works the natural soil is disturbed. So available are small spaces with radically different properties, with abnormal capillarity, with waste materials from construction or other, over-wetted, drained or sealed layers.

Creating favorable conditions for root growth of urban trees is not only a question of the satisfactory growth of the above-ground biomass but also has a crucial influence on tree stability, the risk of tree failure and subsequent potential damage to people and property. (Bühler et al., 2016)

- *Compacted and most often sealed soil in the root zone system*

Both factors obstruct normal gas exchange in the soil and worsen the supply of oxygen and water to the roots. With content of oxygen below 11% in the soil, root growth is suspended (Streckenbach, 2012b) This, in turn, restricts the tree from the ability to absorb water and nutrients from the roots and ultimately leads to retention of growth and poor development of trees (Roloff, 2008);

- *Limited tree capacity for supply of nutrients* which are the result from the disorder in natural circularity and anthropogenic impact on the soil. Under these conditions, not only is there a real lack of essential nutrients but the nutrient intake of trees is limited due to insufficient fine roots (Roloff, 2013a);

- *Increased pH values of soil*, most often as a result of using of limestone-rich building materials when laying pavements. Tree requirements towards the soil solution reaction are largely specific but, in general, elevated pH values complicate the absorption of nutrients;

- *Salting the soil in winter*

Results from some studies prove the extremely negative impact of these saltings on street trees such as – demolition of the soil structure and difficult growth, leaf necrosis formation, drying of branches and gradual dying of whole trees. (Roloff, 2008; Petersen, 1982; Zolg et al., 1983; Zolg et al. 1983b)

- *Mechanical damage to stems and root system* from vehicles and pedestrian traffic as well as from pruning trees while ensuring traffic safety.

- *Damage to the trunk and root system from dog urine*

The urine contains high concentrated salts, especially nitrogen, phosphorus, and sulfur compounds, which damage sensitive species. Initially, the bark of the affected areas is destroyed, and after a time the wood begins to rot (Roloff, 2008; Street Tree Management in Barcelona, 2011).

- *Specific microclimatic conditions against the background of the aggravated macroclimatic environment* in the city – this means higher temperature and lower air humidity, a high concentration of carbon dioxide, the impact of the reflected lighting of buildings and floor coverings. As a result, prolongation of vegetation time is observed, which in turn means a greater need for water and nutrients (Roloff, 2008);

- *Existence of artificial lighting*, the impact of which on the trees' physiology is not yet well studied, but in any case, it creates conditions that are different from those in natural habitats (Bennie, et al., 2016)

One of the negative impacts is that the annual cycles of growth and reproduction in trees controlled by day length can potentially be altered by supplemental night lighting. (Chalker-Scott, L., Chaney, W.R., 2015).

The list of visible effects of trees' efforts to adapt to unfavourable growth conditions as well as the symptoms of deterioration of their living state is long, but the most important are the following: decreased vitality and resistance against diseases and pests, leaf necrosis, premature leaf fall, dried branches, and progressive dying of branches and whole plants.

As a result of the unfavorable soil conditions for street trees, it is also common the movement and expansion of root system in the surface soil layer. Apart from damage to the pavement, this leads to the development of a superficial root system and a reduction in tree wind resistance. The risk of uprooting by storms and wet snow is also increased.

The phenological state and aesthetic qualities of decorative trees in Sofia show that trees placed in unfavorable conditions (pavements and near roads) are losing their decorative qualities much faster. These trees often suffer from necrosis and disorder in their phenological cycle compared to those trees placed under more favorable environmental conditions (away from the street lane or in grasslands) (Kuleliev,1994; Jeleva,1975).

THE OTHER SIDE OF THE PROBLEMS IN STREET LANDSCAPING

The other side of the problems is the damage that the root system causes on the pavements and the underground infrastructure.

The main factors that influence the direction of tree root growth and which manage it are density and moisture of the soil as well as oxygen contents of the soil (Streckenbach et al., 2010; Heidger, 2001). As a result of 10-year college studies at the University of Hannover, it has been found that the limiting factor for root system growth is not the lack of moisture, but the air contents in the soil. The minimum value is 10%. (Streckenbach, 2012b; Heidger, 2001).

From some registered examples of roots of the street trees that are entering in the underground infrastructure, as well as targeted surveys, it is clear that roots are growing where they do not encounter resistance on their way.

This road most often leads them in the light substrate and the filling material of the underground pipelines, in the drainage ditches, around the surface water drainage facilities, to the surface layers of the pavement and even in the joints between the individual elements from which the coating is built.

When after reaching areas with non-thickened soil, roots usually grow there - most often parallel to the pipelines and around them. However, problems arise when pipelines are in poor condition and are not sealed properly. Then the root tops fall into cracks or in an unsealed place, mostly between connecting elements, they enter there, start to divaricate, then fill the whole space and clog it. Rarely, roots cause problems with their growing thickness, exerting mechanical pressure.

Root striving to grow in soil areas with better air circulation and oxygen contents is also the cause of damage to the pavements.

Management techniques that re-establish appropriate soil profiles should be employed to minimize the risks of root invasion along fractured profiles which might subsequently see root proliferation in the region of underground services or the foundations of hard structures. (Moore, G.M, 2008).

MODERN TECHNOLOGIES FOR STREET LANDSCAPING CONSTRUCTION

For decades, foreign science and practice in the field of landscape architecture and construction have been developing tree planting technologies, realizing their exclusive role for urban areas, especially for the big ones. To avoid the impact of all the above-mentioned factors on the street trees as well as the damage from their root system and to preserve and shape street space as a complete living environment with their presence, new devices and technologies are being developed and established. The main directions are:

- *Constructing underground structures for the root system*

They provide greater root space and protect the soil from compaction. They represent an underground cell structure that absorbs road and pedestrian traffic loads. The structure's size can be different and to comply with the requirements of the trees intended for planting. It also creates a large root-permeable space, and with that maximizes the possible usages aboveground.

This structure is filled with a non-thickening substrate. Unsealed pavements provide a perfect opportunity to infiltrate surface water. This way the roots find enough space for development and all necessary conditions - high porosity, oxygen, water, nutrients. This means that street landscaping will be able to perform its functions in the best way.

These systems also solve another problem - the contradiction between the requirements of the normative documents on the required planting area around the trees and the need for these areas to be used for other purposes.

Underground structures and products are used in a variety of projects, but above all - when planting trees in paved areas - streets, pedestrian areas, squares and car parks. They are made from synthetic materials or metal, from individual modules or as complete products. An example scheme is shown in Figure 1.

- *Construction of root protection bridges*

These are products and technologies that are designed to integrate existing trees in a new construction site of paved areas or when the installation of underground structures is impossible.

It is known that preserving existing trees is a very important task for any project, but their root system usually reaches a far distance from the stem – where pavements' base should normally be laid. In many cases, a part of the root system is cut and destroyed, to achieve the construction task. The root bridges overcome the roots near the surface and make possible laying the pavement cover without foundation. Providing the required load capacity at a considerably lower thickness, the root bridges release the surface space for the adult trees' root system, so no roots need to be cut, and soil compaction is prevented, and normal oxygen access is ensured.

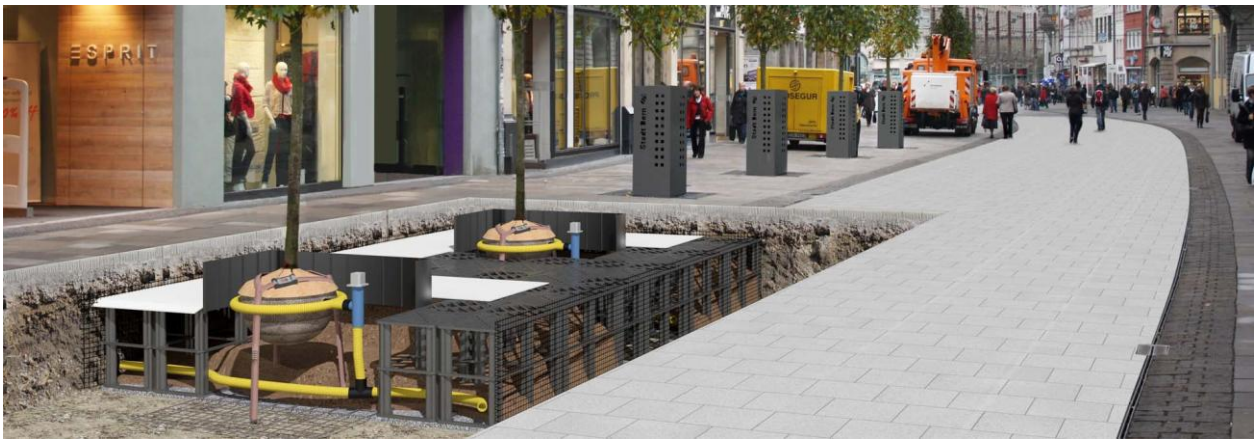

***Fig.1**. Underground structure of modular synthetic products for trees' root system, located in paved areas (https://www.greenmax.eu/de/silvacell/)*

The variety of products that act as root bridges is large, but there are two different types:

- *Grids that lie on foundations.* The foundations have a small cross-section and are clenched in the soil between the roots.

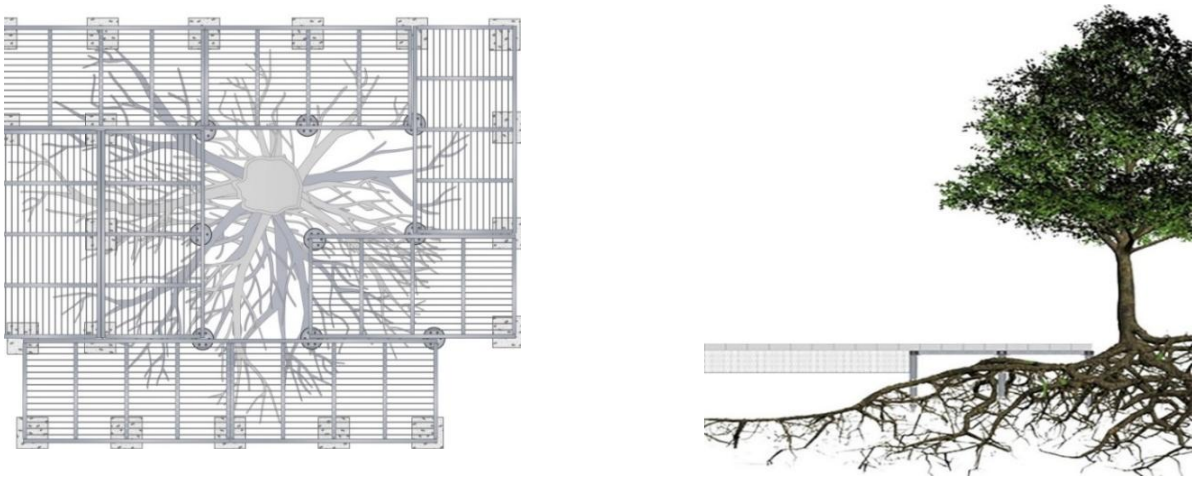

***Fig. 2.** Example of Root Bridge Diagrams - Grid on Turning Foundation. (www.humberg-baumschutz_07-wurzelschutzbruecken*

In practice, this method saves the root system, because for the grids' foundation it is not necessary small thickness and again can replace the bonding and the high resistance to pressure, they absorb and reallocate the traffic load.

They are especially used for a situation where the substrate around the trees has a low to dig up the soil with the roots (Figure 2);

- Grid modular panels, which also have a pavements' foundation. Because of the flexible load-bearing capacity. Also, sealing of the surface layer is reduced. The open structure allows the creation of a second upper surface where the roots cannot damage the pavement (Figure 3).

***Fig. 3**. Laying of ground flooring with a root bridge module (sandwich panel). (https://www.greenmax.eu/nl/sandwichpanel74)*

- *Construction of systems and products for watering and aeration*

Irrigation and supply of air to the roots of trees in an urban environment is vital to them. But under the paved areas where the root system of the street trees is located, this cannot be done in the usual way from the top without the presence of a special system. The different application of pipes in the area of the root system for irrigation and aeration has been applied in European countries for decades, and these systems are constantly improving (Figure 4).

Modern systems are designed in such a way that the supply of water and nutrient solutions, as well as the access of air, can take place from the same place, without the water being able to stay in the air supply pipes. The systems allow optimizing gas exchange by removing CO2 from the soil and supporting its supply of nutrients and moisture (Figure 4).

By combining underground structures with watering and aeration systems, long-term normal growth and development conditions for trees are created (Figure 1).

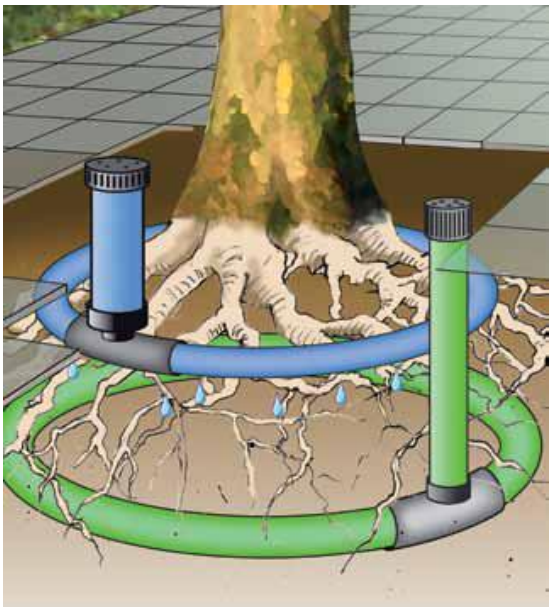

***Fig. 4.** Example scheme of irrigation and aeration system https://www.greenmax.eu/de/aquamax-bewasserung/*

- *Use of underground anchoring systems for newly planted trees*

The specific features of present day's streetscape, as well as design requirements, require new, individual solutions to anchor newly planted trees. Underground anchoring systems are specifically designed for such conditions. They consist of some broad belt straps which are

fastened to the soil by flat steel anchors. A variety of non-natural ground objects is also constructed, where attachments are made to different building elements, most commonly a metal mesh or grid. This way of anchoring trees does not interfere with their natural wind movements and stimulates the normal development of the roots. The top coconut disc protects the root balls from injury, limits the load on the root ball and ensures its integrity (Figure 5).

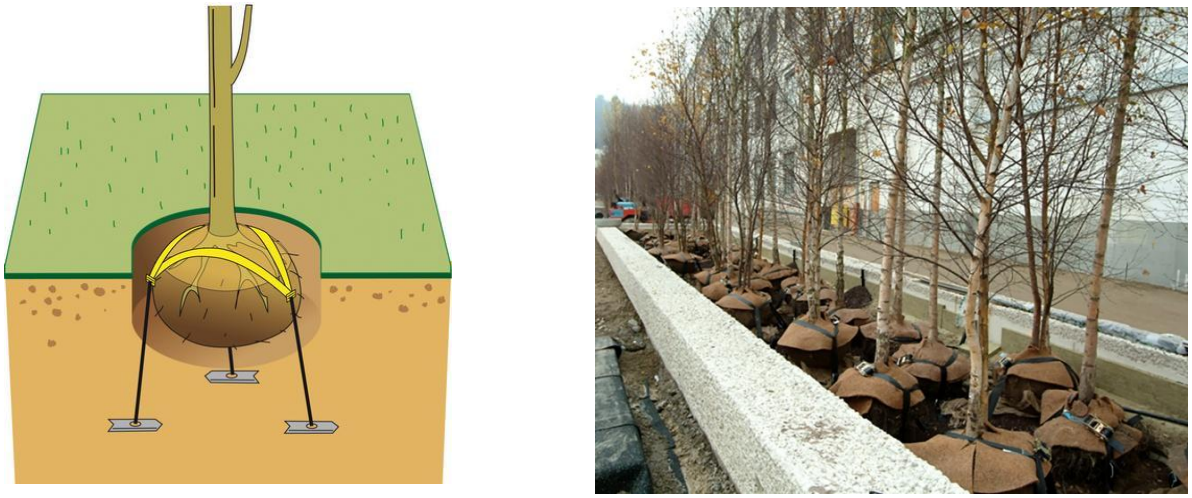

Fig. 5. *Systems for underground anchoring of newly planted trees – stripe of high-density trees (https://www.greenmax.eu/de/wurzelballenverankerung/)*

- *Use of root protection and root guide barriers*

When increasing sealed terrains in urban areas, uncontrolled root growth causes major damage to pavements and underground infrastructure. Root protection and root guide systems and devices are used to solve this problem. Depending on how they function, the systems are divided into two groups – root protection barriers and guiding barriers. However, both systems protect the various elements from the impact of the roots and seem the same at first sight. But there is a difference, which is in detail. The protection ones have smooth walls. Reaching them, the roots spiral inside the barrier, most often turning left (Figure. 6, a-left).

a) b)

Fig. 6*. Schemes for using root barriers - a simple root protection (a - left) and root-guiding barrier (b - right) (/www.rootbarrier.de/produkte/wurzelschutz, www.greenmax.eu/en/treerootguide/*

The root guiding system walls have a vertical ribbing that takes the roots down the ribs to the bottom of the used product. From there onwards, at a greater depth, they develop horizontally or vertically, as is their natural growth path, and stabilize the tree in an optimal way (Figure 6, b - right). Two major factors determine which system to use - the size of the space allocated to the trees' root system, and what role the system has to have.

The root protection products are used when a free-root zone has to be created, for example, to protect underground cables or pipes from the roots of the trees. But it should be used only when enough space for the root system for the tree is provided. This means the distance between the barrier and the stem is at least 2-2,5m. The barrier is applied to prevent uncontrolled horizontal or vertical growth of the roots.

CONCLUSIONS

In the conditions of aggravated urban environment, conventional tree planting technologies do not provide opportunities to build long-lasting street tree stands of acceptable aesthetic value and good health. They also are not suitable due to the problems that rise in the underground infrastructure elements and the street pavement from the growth of the trees. Unfortunately, these technologies in Bulgaria are still the only ones used.

Surveys of the up to date practices and technologies for street landscaping in European practices show that there is no obstacle for introducing them in our country as well. For the future construction of new streets or complete reconstruction of existing ones, in large urban areas or where conditions are already aggravated or are expected to become so, the application of all the above-mentioned technologies is imperative. Only in this way can the street landscaping fulfill its role and justify the hopes of maintaining an ecological and healthy environment for the future decades.

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