Cellweb tree root protection (TRP): System specially designed to protect trees and their root system

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ABSTRACT: When construction occurs in areas close to existing trees, the roots can be particularly vulnerable and it's necessary to use systems that do not inhibit construction and, at the same time, protect the trees and their root system. According to the British Standard BS5837:2012 the design in Tree Root protection areas should not require excavation into the soil and avoid localized compaction, preserving the zone completely undisturbed. The majority of tree roots will grow in the top 600mm of soil and when the soil is compacted, it will adversely affect drainage, gas exchange, nutrient uptake and organic content, and will seriously impede or restrict root growth. A Cellweb confinement system was specifically designed for root protection area (RPA). The system creates a stable no-dig solution, load bearing structure for traffic and reduces the stress in the subgrade soils. This system confines aggregate materials and ensures that the load placed upon it is laterally dissipated rather than transferring to the soil and roots below. The system is comprised of three key elements: Cellweb TRP to support and distribute the applied load on the surface, Geotextile Treetex(Nonwoven geotextile) used as a separator and pollution control and a selected clean angular stone 4-20 mm used as infill material which is self-compacted.
The design using this system is based on the reinforcement of unpaved roads proposed by Webster (1981) and adapted to the system using the bearing capacity analysis.

Keywords: geocells, soil reinforcement, Tree Root Protection, No-dig solution, Cellular confinement system, ground improvements.

1 INTRODUCTION

Climate change continues to be driven by human activities that release greenhouse gases such as carbon dioxide into the atmosphere. Trees are important elements of green infrastructure, provide numerous environment, economic and social benefits.

While they are growing, trees absorb carbon dioxide from the atmosphere through photosynthesis and store it as carbon in the form of wood. Carbon dioxide is the most important greenhouse gas in terms of human activity. Trees represent a key resource that can significantly contribute to climate change adaptation.

During construction works, trees and their surrounding soils are vulnerable to disturbance, injury, environmental changes and often exerts pressures on existing trees. A tree that has taken many decades to reach maturity can be damaged irreparably in a few minutes by these actions.

According to the British Standard "*BS5837:2012 Trees in relation to design, demolition and construction – Recommendations"* the design and construction in tree root protection areas (RPA's) should not require excavation into the soil and avoid localized compaction, preserving the zone completely undisturbed.

A Cellweb TRP confinement system was specifically designed for tree root protection area (RPA). The system creates a stable no-dig solution, load bearing structure for traffic and reduces the stress in the sub-grade soils. This system confines aggregate materials and ensures that the load placed upon it is laterally dissipated rather than transferring to the soil and roots below.

2 BS5837 2012 TREE SURVEY

A tree survey in accordance with BS5837 2012 should be undertaken to record information about the trees on or adjacent to a site. The tree protection plan should propose a series of mitigation measures to improve the soil environment that is used by the tree for growth. The relevant information about potential issues should be recorded.The objective should be to achieve a harmonious relationship between trees and structures that can be sustained in the long term. Two of the most crucial elements of the survey are the assigning of a tree retention category and calculation of a root protection area (RPA).

2.1 *Tree categorization method*

Trees should be categorized using the Figure 1. The purpose of the tree categorization method is to identify the quality value (in a non-fiscal sense) of the existing trees in order to determine which trees should be removed or retained in the event of development occurring.

	1 Mainly arboricultural qualities	2 Mainly landscape qualities	3 Mainly cultural values, including conservation
Trees to be considered for retention			
Category A **Trees of high quality** with an estimated remaining life expectancy of at least 40 years	Trees that are particularly good examples of their species, especially if rare or unusual; or those that are essential components of groups or formal or semi-formal arboricultural features (e.g. the dominant and/or principal trees within an avenue)	Trees, groups or woodlands of particular visual importance as arboricultural and/or landscape features	Trees, groups or woodlands of significant conservation, historical, commemorative or other value (e.g. veteran trees or wood-pasture)
Category B **Trees of moderate quality** with an estimated remaining life expectancy of at least 20 years	Trees that might be included in category A, but are downgraded because of impaired condition (e.g. presence of significant though remediable defects, including unsympathetic past management and storm damage), such that they are unlikely to be suitable for retention for beyond 40 years; or trees lacking the special quality necessary to merit the category A designation	Trees present in numbers, usually growing as groups or woodlands, such that they attract a higher collective rating than they might as individuals; or trees occurring as collectives but situated so as to make little visual contribution to the wider locality	Trees with material conservation or other cultural value
Category C **Trees of low quality** with an estimated remaining life expectancy of at least 10 years, or young trees with a stem diameter below 150 mm	Unremarkable trees of very limited merit or such impaired condition that they do not qualify in higher categories	Trees present in groups or woodlands, but without this conferring on them significantly greater collective landscape value; and/or trees offering low or only temporary/transient landscape benefits	Trees with no material conservation or other cultural value

Figure 1. Chart of tree quality assessment – Trees to be considered for retention. (*BS5837:2012)*

2.2 *Root Protection Area (RPA)*

The Root Protection Area (RPA) to maintain the tree's viability should be calculated. It is the minimum circled area around a tree which is deemed to contain sufficient roots and soil, and where the protection of the roots and soil structure is treated as a priority. The area has a radius relative to the tree trunk diameter, measured at 1.5m above the ground.
For single stem trees, the RPA is calculated as an area equivalent to a circle with a radius 12 times the stem diameter. For trees with more than one stem, one of the two calculation methods below should be used:

a) For trees with two to five stems, the combined stem diameter should be calculated as follows:

$$\sqrt{(stem\ diameter\ 1)^2 + (stem\ diameter\ 2)^2 \ldots + (stem\ diameter\ 5)^2}$$

b) For trees with more than five stems, the combined stem diameter should be calculated as follows:

$$\sqrt{(mean\ stem\ diameter)^2 * \ number\ of\ stems}$$

The RPA for each tree should initially be plotted as a circle centered on the base of the stem.

3 STRUCTURAL REINFORCEMENT DESIGN

By confining the clean angular infill material, Cellweb TRP confinement system works by altering the angle of load distribution, reducing the pressure on the soil and increasing the bearing capacity. This ultimately minimises soil compaction and maintains a pervious soil structure. This is crucial for continued water permeation and gas exchange into the rooting environment.

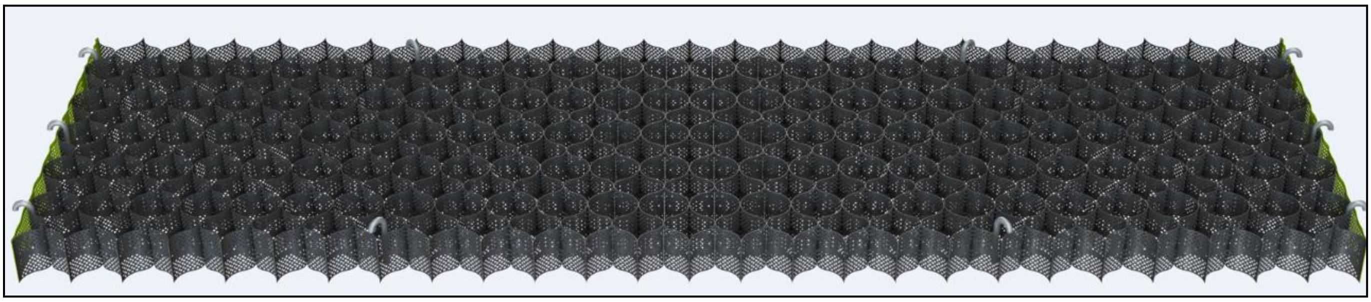

Figure 2. Cellweb panel full expanded. L=8.56m, W=2.56m.

The structural reinforcement design using Cellweb is based on the guidance provided by Webster (1981) which uses conventional bearing capacity analysis to determine the applied and allowable pressure below the road pavement. These equations are based on an unpaved design, we are not taking into account any surfacing over Cellweb.
The design process is as follows:

Step 1. Radius of contact depending on traffic load:

$$R = \sqrt{\frac{P}{p\pi}} \tag{1}$$

where R = radius of contact patch (m), P=wheel load (kN), p = tyre pressure (kPa)

Step 2. Bearing Capacity of subgrade:

$$q_a = cN_c \tag{2}$$

where c = undrained shear strength of soil (kPa), Nc = bearing capacity factor (dimensionless), Nc = 2.8 (Steward et al, 1977).

Step 3. Applied pressure on the subgrade at the top and base of the Cellweb using the stress distribution equations below (Boussinesq, 1885):

Vertical pressure at top of Cellweb, q_{vt} is given by

$$q_{vt} = p\left[1 - \frac{1}{\left(1 + \left(\frac{R}{d_t}\right)^2\right)^{\frac{3}{2}}}\right] \tag{3}$$

Vertical stress at the base of the Cellweb layer q_{vb} is given by

$$q_{vb} = p\left[1 - \frac{1}{\left(1+\left(\frac{R}{d_t}\right)^2\right)^{\frac{3}{2}}}\right] \quad (4)$$

where dt = Depth from top surface of subbase to top of Cellweb, db = Depth from top surface of subbase to bottom of Cellweb.

Step 4. Calculate the lateral pressure at the top $q_{ht,}$ and bottom q_{hb}, of the Cellweb:

$$q_{ht} = K_a q_{vt} \quad (5)$$

$$q_{hb} = K_a q_{vb} \quad (6)$$

$$q_{hav} = \frac{q_{ht}+q_{hb}}{2} \quad (7)$$

where $Ka = tan^2\left(45° - \frac{\phi}{2}\right)$, ϕ = angle of shearing resistance of the infill material, qv = vertical pressure at top or bottom of Cellweb as appropriate.

Step 5. Reduction of the vertical pressure due to stress transfer from the granular infill material to the Cellweb walls:

$$q_r = 2(H/D)q_{hav}\ tan\,\delta \quad (8)$$

where H = height of Cellweb (m), D = Diameter of Cellweb pockets (m), δ = Angle of shearing resistance between Cellweb wall and infill material for the clean angular 4mm to 20mm material used in tree root protection applications the reduction in friction is estimated to be about 0.8. So δ = 0.8ϕ

Step 6. Increase of the subgrade bearing capacity due to vertical pressure reduction:

$$q_{cw} = q_a + q_r \quad (9)$$

Step 7. Total thickness of Subbase using Boussinesq's equation:

$$d_{cw} = \frac{R}{\sqrt{\frac{1}{\left(1-\frac{q_{cw}}{p}\right)^{\frac{2}{3}}} - 1}} \quad (10)$$

Required additional subbase (m)

$$S_{r\,=}\ d_{cw} - cellweb\ thickness - dt \quad (11)$$

where Sr = required additional subbase (m), dt= protection clean angular stone overfill thickness(m)

4 CELLWEB TRP SYSTEM – CASE STUDIES

Cellweb TRP is a cellular confinement system that was specifically designed for root protection area, it confines aggregate materials and makes them stronger, thus increasing the bearing capacity of the sub-grade (see Point 3). The infill material doesn't need to be compacted inside of the cells due to the confinement offered by the system.

Research (see report on trial pavement construction using Cellweb pavement reinforcement. Revision 1.2. The Environmental Protection Group) shows that Cellweb TRP acts as a stiff raft to distribute wheel loads, thus maintaining the soil bulk density and helps promote oxygen exchange between soil and air at levels that are suitable for tree root growth.

Figure 3. Left Side: Cellweb panel unexpanded. Right side: Cellweb filled with Clean Angular Stone 4-20mm.

The Cellweb TRP system comprises three key elements:

- **Cellweb TRP** (HDPE), confines the infill material ensuring that the load placed upon it is laterally distributed, reducing the load on the soil and increasing its bearing capacity. This ultimately minimizes soil compaction.
  The walls of the cells are perforated and when filled with the clean angular stone 4-20mm enable free movement of water and oxygen, maintaining the tree roots requirements.
- **Geotextile Treetex** (Nonwoven geotextile) has two functions: separator and pollution control.
  It separates the infill material from the soil beneath and it prevents contaminants from reaching the roots within its structure and allows it to degrade aerobically.
- **Selected clean angular stone 4-20 mm** used as infill material. Having an angular stone allows a better distribution of the load providing rigidity through the cells and also allow pore spaces for the diffusion of water and gasses. The permeability of the infill material won't be reduced inside the system.

4.1 *Case study: new development off Keats Way, Rushden, Northampton.*

Geosynthetics Limited were approached by JPP Consulting Civil and Structural Engineers regarding a new residential development on land off Keats Way, Rushden Northamptonshire. The only feasible route for the new road would pass through the RPA of a large Beech tree. The Beech was considered to be of high amenity value and was to be retained within the new development, which meant that a 'no dig' tree root protection system would need to be used for the construction of the access road.

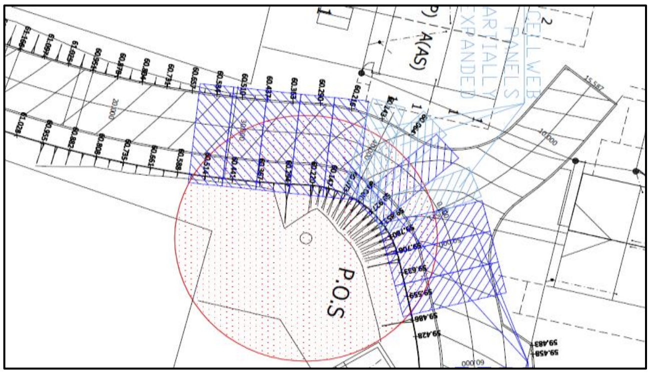

Figure 4. Shows the proposed route of the new access road passing through the RPA of the Beech tree, as out lined by the red circle. The blue hatched panels across the width of the access road denote panels of Cellweb TRP.

More often than not, the system is installed on relatively level sites. In this case study we will look at how Cellweb TRP has been used to overcome significant changes in levels within the RPA, while maintaining a healthy environment for tree roots. Over the length of the access road there was a fall in levels of 2.4m from the southern end of the road at Keats Way to the Northern end of the road in the new development.

Figure 5. Installation the Cellweb TRP system with the Geotextile and clean angular material.

The new access road is surfaced using permeable blocks, allowing continued water permeation and gaseous exchange. The remaining road outside of the RPA is constructed using a conventional subbase with an asphalt surface.

Figure 6. Completed access road using Cellweb TRP system and permeable block paving as surface.

4.2 *Case study: Castle Gardens, Leicester*

The council engaged Geosynthetics Limited and Levitate Architecture and Design Studio Limited to design a no dig 3D cellular confinement system. The solution protected the existing trees, minimised compaction of soils, reduced overall footprint and eliminated root severance, whilst providing continued water permeation and gaseous diffusion to the rooting environment beneath.

Leicester City Council identified the need for a new entrance and footpath through Castle Gardens on the out skirts of the city centre. The challenges were a change in levels of 2.19m and presence of mature tree RPA's along the route dictating that a no dig solution was required for the footpath construction. The ramp was built in 3 tiers

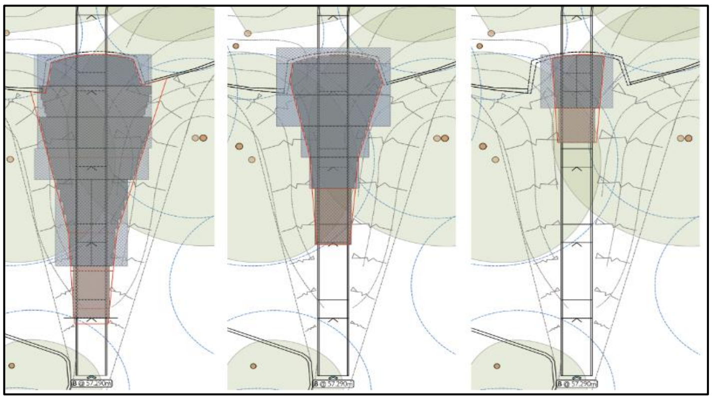

Figure 7.Cellweb TRP system tiers to build the ramp.

Figure 8. Left side: installation of Cellweb TRP system. Right side: Finished pathway with permeable resin bond surface.

5 CONCLUSION

A Cellweb TRP system is an appropriate confinement system to reduce further subgrade stress and compaction applied by vehicular loading. The bulk density of the existing subgrade will be increased if we compare it with standard compacted construction method, it creates a harmonious relationship between trees and structures that can be sustained in the long term.

The system creates a stable, no-dig solution that avoids excavation in tree root protection area (RPA). This system confines aggregate materials and ensures that the load placed upon it is laterally dissipated rather than transferring to the soil and roots below.

The system is comprised of three key elements: Cellweb TRP (HDPE) to support and distribute the applied load on the surface, Geotextile Treetex (Nonwoven geotextile) used as a separator and pollution control and a selected clean angular stone 4-20 mm used as infill material, creating a pervious structure that allows water and gas exchange.

In conclusion the beneficial effects for tree roots of using Cellweb TRP system are as follow:

- Minimizes compaction of the soil beneath.
- Allows oxygen, carbon dioxide and water exchange between soil and air.
- Pollution control. The system prevents pollutants and contaminants from reaching the roots.
- The permeability of the infill material won’t be reduced inside the system.

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