ESTABLISHING TREESCAPES IN CHALLENGING URBAN IN-FILL DEVELOPMENTS

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Background

The concept design for the redevelopment of a former paper mill in Alphington, Melbourne featured medium density housing with attractive streetscapes in an exclusive inner-city environment. The design promised superior amenity, and central to this was a green environment.

The landscape design included trees and garden beds. Feature trees of the development included *Corymbia citriodora* and *Corymbia maculata*, trees popular in Melbourne in view of their stately form, relative hardiness, and ability to cope with a wide temperature range.

Works commenced on site in 2017 with stripping of topsoil. Not untypical of in-fill developments, the project was characterised by spatial constraints including limits for stockpiling. As a result, all topsoil was removed off site and disposed of.

I was consulted in May 2018 with a request for guidance on structural soils. Structural soils had not been part of the original design; strata vaults had been specified. However, the pressure on space meant that root zones were shared with all services and any future maintenance, repair or replacement would be strongly impeded by strata vaults. As a result, structural soils were recommended.

Soil challenges

A review of the landscape design for the site showed that a number of different soils were required. Along with structural soils there was a strong emphasis on Water Sensitive Urban Design (WSUD) outcomes, raingardens and display garden beds. Soil specifications were developed for each of these different landscape elements which included high infiltration tree pit soils for the WSUD element.

However, the first site inspection revealed that the topsoil stripping had left the remnant tertiary basalt clay subsoil as the palette on which the green infrastructure would be developed (figures 1a & 1b).

Figures 1a and 1b. Dense clay subsoils excavated for tree pits. Note the smearing of the clay (right) by the excavator bucket.

Testing of the clay confirmed an extremely hostile medium, not only physically, (figures 1a & 1b) but also chemically (table 1 and figure 2).

Analyte	Target values for subsoils	Sample 1	Sample 2
pHw	5.5 – 7.5	8.49	8.13
EC (dS/m)	< 0.5	0.23	0.69
Sodium mg/kg	<300	1506	1696
Chloride mg/kg	<200	155	732
Sodium %CEC	<10	30.8	29.2
Calcium %CEC	>50	14.7	12.6
Magnesium %CEC	15 - 30	52.1	57.1
Potassium %CEC	2 - 7	2.2	1.2

Table 1. Subsoil chemistry at the Alphington site.

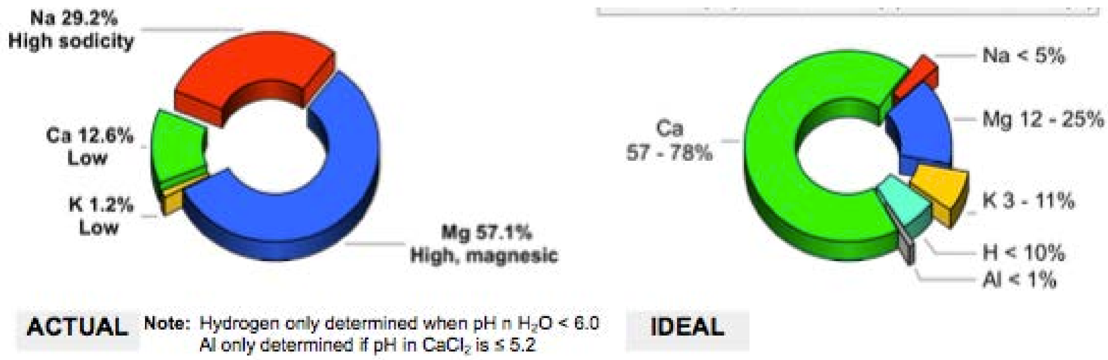

Figure 2. Graphical representation of tested vs. ideal cation balance (note ideal proportions are shown for topsoil – refer table 1).

Figure 2 is a reproduced graphic from the soil tests which shows the degree of imbalance between the tested soil (left) and the ideal soil (right). It is important to note that we do not generally expect subsoils to achieve 'ideal' status. However, the degree of departure from the ideal is what we assess and what determines potential remedial action.

When contrasted with the ideal cation balance it is immediately evident that the soils are completely unbalanced. In simple terms, plants will struggle to grow without amendment. A brief explanation follows.

The cations (calcium, magnesium, potassium, sodium) are – in addition to being important plant nutrients – central to soil structure. A dominance of calcium is necessary to support chemical flocculation and aggregation of soil particles. When magnesium and sodium dominate, flocculation and aggregation are extremely weak and this results in dispersive soils (soils which totally or partially 'dissolve' in fresh water) and loss of soil structure (the arrangement of solids and pores). In practice, and what happened on the Alphington site, is that soils effectively collapse on themselves and in the process lose their pore structure and their ability to breathe. Roots cannot grow in this medium. This is unfortunate because they can hold substantial stores of water during dry conditions.

The design featured trees at set intervals along each street in the development. It was initially assumed that individual pits would be excavated for each tree. Tree performance is substantially improved where root zones are shared. This is due to the fact that tree root exploitation of a given soil volume is not particularly 'efficient'. Enhanced growth is also likely due to the reported collaboration between trees growing together. Where trees can share a particular soil volume, roots can overlap and maximise the use of available topsoil without overly competing with each other. The initial recommendation therefore was that contiguous tree pits be constructed.

The trench shown in figure 1 became the standard for tree pits across the development. Options to increase the size of pits were explored but were rejected in view of spatial constraints. Tree pits were positioned under footpaths and laybacks and trees were confined to this narrow alignment.

Once it was determined that structural soils were the only acceptable medium for load-bearing structures, the issue of tree root volumes arose. It was immediately apparent that the competing demands of tree root volumes and available space between roadways, footpaths, services and private gardens represented significant challenges.

Tree root volumes

Calculation of soil volumes is determined by a number of factors including tree size and expected longevity, tree pit soil type, surrounding soil type, irrigation / passive watering, surrounding surface (i.e. natural soil or sealed concrete etc.), and climate. In the Alphington development, passive irrigation was planned and soil amelioration outside the tree pit was required.

On these bases, the recommended minimum soil volume in natural soil was 22m^3 per tree for the selected species. Soil volumes were reduced by trees sharing the same tree pit. Soil volumes for shared rooting zones were calculated as follows:

- Three trees per pit – total soil volume of 45m3
- Six trees per pit – total soil volume of 77m3
- Seven trees per pit – total soil volume of 88m3
- Eight trees per pit – total soil volume of 100m3

The use of structural soil greatly increases the volume of soil required – by a factor of 5. Structural soils are comprised of a 5:1 blend of large (63mm) ballast and filler soil. Therefore the recommended structural soil volume was 110m3 per tree. In the case of shared root zones, this figure was adjusted downward as per the figures for natural soils above, times 5 (i.e. where the volume requirement for eight trees in natural soil is 100m^3, the volume will be 500m^3 for structural soil). Any shortfall from the required root volumes had to be met by soil outside the tree pit. In some situations, tree volumes were met by structural soils only; in others, soil volumes were met by a combination of structural soils and surrounding soils.

However, a review of figure 1 reminds us how hostile surrounding soils were and this included hostility to amelioration. The density of soils – and hardness when dry and plasticity when wet – meant that incorporation of ameliorants was extremely difficult.

Our prescription included application of gypsum as the primary chemical ameliorant, at rates of 1kg/m^2.

This equates to 10t/ha, an extremely high application rate. Given that gypsum is poorly soluble – about 2g/L – the application rate meant that a supply of gypsum is available to continue working on these soils as trees grow and roots attempt to penetrate these dense soils. We also recommended that the glaze (figure 1b) on the sides and bottom of the tree pits be broken by the teeth of an excavator bucket. Shattering, or roughening the sides of the tree pits aimed to increase the soil surface area on which the gypsum could work. The importance of conditioning site soils ahead of works was emphasised to maximise the amount of site soil that could contribute to overall soil volume requirements.

Detailed investigation and design by the consulting engineers was successful in integrating the spatial requirements of tree root volumes in most locations. However, in some locations sufficient space was not available. Our recommendation in these locations was to allow the use of structural soils beneath carriageways. This would have provided ample root volume for the large trees but the proposal was met with caution by Council who would by default become the authority with responsibility for long-term maintenance of the road assets. They were concerned about the risk of differential settlement between sections of the road underpinned by structural soils and sections underpinned by conventional pavement sub-grade. Our argument was that structural soils could easily deliver a 98% Proctor compaction similar to conventional sub-grade design.

We researched the literature for evidence of structural soils being used under road carriageways and consulted with the City of Melbourne, the City of Greater Bendigo and Hume City Council, all of which have used structural soils extensively. We also contacted Professor Jason Grabosky, an urban tree expert from Rutgers University in New Jersey, USA.

Whilst all have used structural soils under parking and footpaths, none was able to cite an example of the use of structural soils under carriageways. SESL had previously designed structural soils for private internal roads in the Olympic Park in Sydney and while these roads are traversed by various levels of traffic including garbage trucks and service vehicles, they are not public roads and responsibility for their maintenance rests with the Olympic Park Authority. The recommendation to use structural soils under carriageways was rejected.

Soil handling and management

Our work on specifying structural soils, and agreement on soil preparation and tree root volumes, was temporarily settled. We proceeded to specify soil properties for the non-structural soil tree pits, garden beds, and biofiltration beds. The non-structural soil tree pits (hereafter referred to as 'tree pits') were part of the WSUD aspect of the design. These soils were designed to allow rapid infiltration while also ensuring sufficient water and nutrient holding capacity to sustain healthy tree growth.

Again, the pressure on space highlighted issues relating to the appropriateness of placing structural soils contiguous with tree pit soils or biofiltration soils. Concern was raised of the risk of particle migration from the tree pits or biofiltration beds into the coarser structural soils potentially creating 'wash-out' zones in tree pits and reducing the effectiveness of the structural soil. The use of geofabric to prevent migration of tree pit soil was proposed.

Tree pit soils are designed for high flow stormwater ingress. Stormwater can have high velocity due to low resistance of pavements. However, the design of the kerb invert aimed to reduce the energy of stormwater entering the tree pit. Rock mulch was proposed to absorb the energy of inflowing stormwater. This results in water diffusing down the soil profile at 100-200mm/hr as specified in the Specification for Tree Pit Filter Media. This rate is not high enough to carry soil particles and promote migration of tree pit soil into the structural soil.

It was recognised that some settling of the Tree Pit soil may be expected as the soil 'beds in' to the surrounding structural soils but further migration was considered highly unlikely. It was therefore recommended that Tree Pits were overfilled by 5-10% to allow for settling of Tree Pit soil against the abutting structural soil. Further controls to limit migration of tree pit soil into structural soils were not deemed necessary.

Tree stability

The next issue that arose concerned tree stability. While tree root volumes may be sufficient in a linear tree pit, we were asked to provide an opinion concerning the lateral stability of trees where radial spread of tree roots may be compromised. Whilst a lot of work has been done on lateral spread of tree roots, little work has been done to determine risks to tree stability where radial expansion is constrained.

We called on research we had completed for the Melbourne Quarter development in Docklands which examined the risk from tree roots on a heritage wall. From this and other researches, we recommended that trees should have a minimum radial root expansion of four times the mature bole diameter at ground level. For example, if the mature bole diameter of a mature tree is expected to be 800mm, the minimum distance from the base of the tree to a root impediment should be 3.2m.

In some particularly constrained locations, minimum distances could not be met. The only remaining option for these locations was a review of tree species. The trees were replaced with smaller-growing trees more suited to the available space.

Conclusion

This project was characterised by extensive research that included:

- soil specification for:
  - structural soils,
  - water sensitive urban design tree pit soils,
  - biofiltration soils,
  - garden bed soils,
- soil placement;
- tree root volumes;
- tree health, vigour and longevity, and;
- tree stability.

The project was also characterised by highly professional collaborations between the developer, consulting engineers, landscape architects, and Council. The developers recognised relatively early that substantial work was required to ensure realisation of the design intent. There were many meetings between the parties. Council were fully cognisant of the fact that they would have long-term carriage of site assets (trees, roads etc.) and were careful to ensure that decisions made were in the long-term interests of residents. The developer enjoys a very good reputation in residential and commercial developments in Melbourne and was keen to ensure delivery of quality outcomes. These drivers resulted in constructive engagements and a shared desire to achieve quality outcomes.

From the perspective of the soil scientist, it yet again highlighted the importance of early professional engagement of soil professionals to assess soil conditions to ensure compatibility of design intent with achievable outcomes.