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The Effect of Tree Roots Upon Pavement Behaviour

D.B. McINNES
Senior Lecturer, School of Civil Engineering, South Australian Institute of Technology

SUMMARY Design for pavement thickness purposes sometimes incorporates broad environmental input parameters (e.g. rainfall). However the performance of the pavement is often controlled by local environmental conditions giving rise to service which is contrary to design expectations. Roadside vegetation and its impact upon local environmental conditions needs to be examined in this regard. This paper describes an investigation into the effects of tree roots upon a residential street pavement in Adelaide. By measuring total suction in the laboratory on soil taken from near the tree (a eucalyptus species located in an expansive clay subgrade soil area) the extent of the drying influence of the tree's roots is assessed. The deformed surface shape of the pavement is discussed and related to the soil profile and dessication caused by the roots. The effects of the tree's roots are then examined in relation to the surface deflections developed during the application of a loaded wheel. This discussion presents information in terms of surface deflection measurements using a Benkelman Beam and laboratory measured compression stiffness values. This paper describes an investigation carried out in an area of Adelaide which suffers penalties from premature loss of surface shape of residential streets. Some of this deterioration is known to be due to the planting of trees in the verges of these streets. In addition, advantages offered by carrying out, in some circumstances, routine suction measurements as part of pavement investigation processes are mentioned.

1 INTRODUCTION

A responsibility of the road engineer is to develop a pavement structure which will maintain an acceptable surface shape throughout the expected design life of the pavement. In certain instances trees planted within the verge of a road will reduce the service life of the pavement, sometimes to one half of its intended value. The interaction of the tree and the pavement appears to be most marked during the tree's growth stages, which may extend over several years.

This paper describes an investigation carried out in an area of Adelaide which suffers severe penalties as a result of the use of native tree species, planted within the verge, for residential streetscaping. The work reported has been conducted where up to 10-15 m depth of unsaturated highly expansive soil occurs and where tree root access to ground water is impeded at least during the earlier years of growth. Soil profiles of this general category constitute approximately 30% of the Adelaide metropolitan area. They are also encountered throughout other parts of Australia. It is conservatively estimated that the service life of pavements in these areas is one half of that experienced elsewhere where stable soils exist. This reduction in service life imposes heavy maintenance and reconstruction costs upon road construction instrumentalities.

2 BACKGROUND AND PREVIOUS WORK

2.1 Pavement Distress Caused By Tree Roots

2.1.1 Surface dislocation

Growth of a tree involves an increase in the diameter of its roots which displaces soil. In the case of near surface roots this may be sufficient to cause dislocation (heave) of the pavement surface. This problem may be aggravated on shallow soil profiles where roots are concentrated near the surface.

It is recognised that certain trees e.g. Poplar, Moreton Bay Fig, develop root systems which are more likely to have strong lateral roots near the surface. Consequently planting of these species within or nearby a paved surface is ill-advised from a pavement performance perspective.

2.1.2 Loss of surface shape

In general the gradual loss of surface shape shown by a pavement may be due to volume changes brought on by environmental or traffic induced causes. In areas of expansive subgrade soil, such as that in which the work reported herein was carried out, wetting or drying of the subgrade soils are normally the major cause of loss of surface shape. Traffic loading may simultaneously introduce further effects but the extent of this influence is unknown at present.

Surface levels e.g. Pile 1981, taken in streets so far examined indicate that the ground where trees and pavements interact has been characterised by differential shrinkage, more so than swelling. Some loss of shape due to seasonal swelling and shrinkage near the kerb alignment must also be included.

Permanent surface loss of shape results in cracked and distorted concrete kerbing, ponding of water in areas of flat drainage grades and grossly distorted, cracked, sealed pavements. A dish-shaped depression in the pavement surface and adjoining kerb, and centred on tree locations, is regularly noticed.

It was decided that the drying effect introduced into the pavement environment by the establishment of trees in the areas studied was of major importance.

Measurements for examining the drying effect of trees on civil engineering structures have been carried out only in recent years. In the main this work has concentrated upon foundation design applications, Aitchison et.al.(1977). Richards et. al.(1983) have described more generally the overall effect of vegetation on the drying of clays. This information has shown that total suction measurements carried out on the supporting soil can be used to indicate the influence of vegetation.

A tree, through its root fibres, particularly during dry periods, imposes a demand for water upon the supporting soil. This demand for water is reflected in the total suction of the soil as the roots and soil jointly establish a suction potential. The type of tree, prevailing soil conditions and proximity to ground water will control the extent and magnitude of soil suction response. In this investigation it was decided to use total suction measurements to examine the extent and magnitude of drying at particular tree locations.

Cutler and Richardson (1981) describe how different tree species may have various degrees of impact relating to house damage. Unfortunately relationships between the size and character of the root systems and the extent of drying is not available. Biddle (1983) shows data gathered in the United Kingdom relating to this matter in terms of moisture contents.

In certain localities government authorities have produced information which may be used as a guide in street tree planting. An example of such, is that published by the Government of South Australia (1980) which takes account of the effect of trees on sewers, overhead services and damage to roads and houses. Appendix A at the end of this paper indicates species of trees not permitted in streets as required by the South Australian Sewerage Act 1929 - 1977. Regulation 12.

All of the above information is generally lacking in details regarding the shape and extent of influence of the root system.

The stiffness of pavement subgrade soil responds to changes in soil suction. Richards (1970) provides information relating to the increase in resilient modulus with suction for soil from the subgrade of a pavement at Macalister, Queensland. Pavement design curves clearly show that service life for a given sub-base/base course thickness would be markedly effected by subgrade modulus changes. Very little information is available regarding the change in stiffness of expansive clays with associated total suction changes. It would be expected that these changes would have a major bearing upon rolling wheel surface deflection measurements (Benkelman Beam measurements) which are widely practised for pavement evaluation surveys. Attention was therefore also given in this investigation to examining the influence that tree root drying of the pavement would have on surface deflections. Inferences to be drawn from this part of the study are claimed to be most significant in the general area of pavement service and surface deflection interpretations.

3 FIELD AND LABORATORY MEASUREMENTS

In this section techniques used at a typical tree location will be summarised.

Soil samples were collected from 3 to 4 metre deep inspection trenches excavated close to a tree. Use of trenching provided the opportunity for collecting data on the shape and character of the root system. Variability in the soil profile was also immediately apparent. Figure 1 gives an indication of the soil profile encountered together with soil classification results.

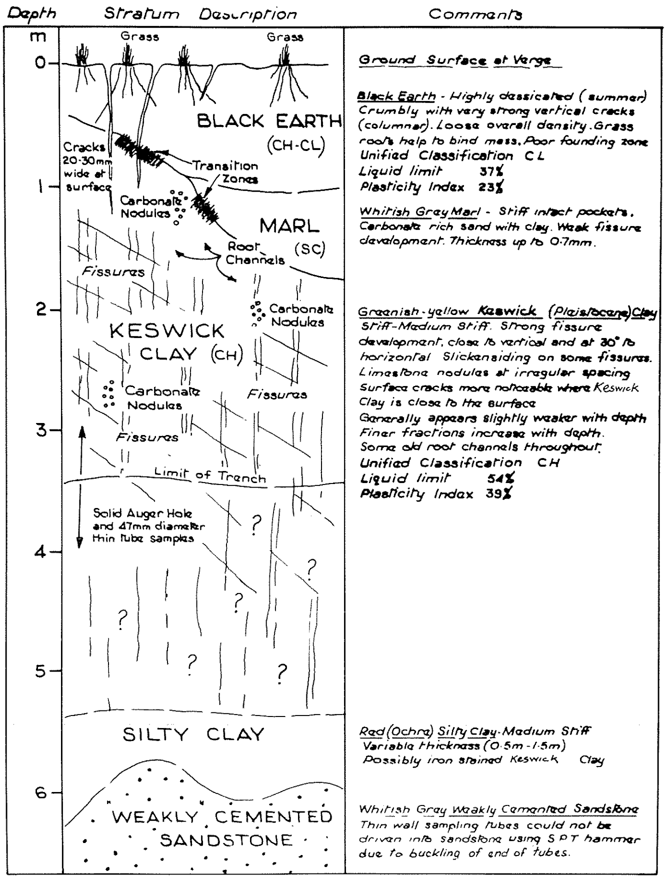

Figure 1 Composite soil profile - Reece Avenue, Klemzig

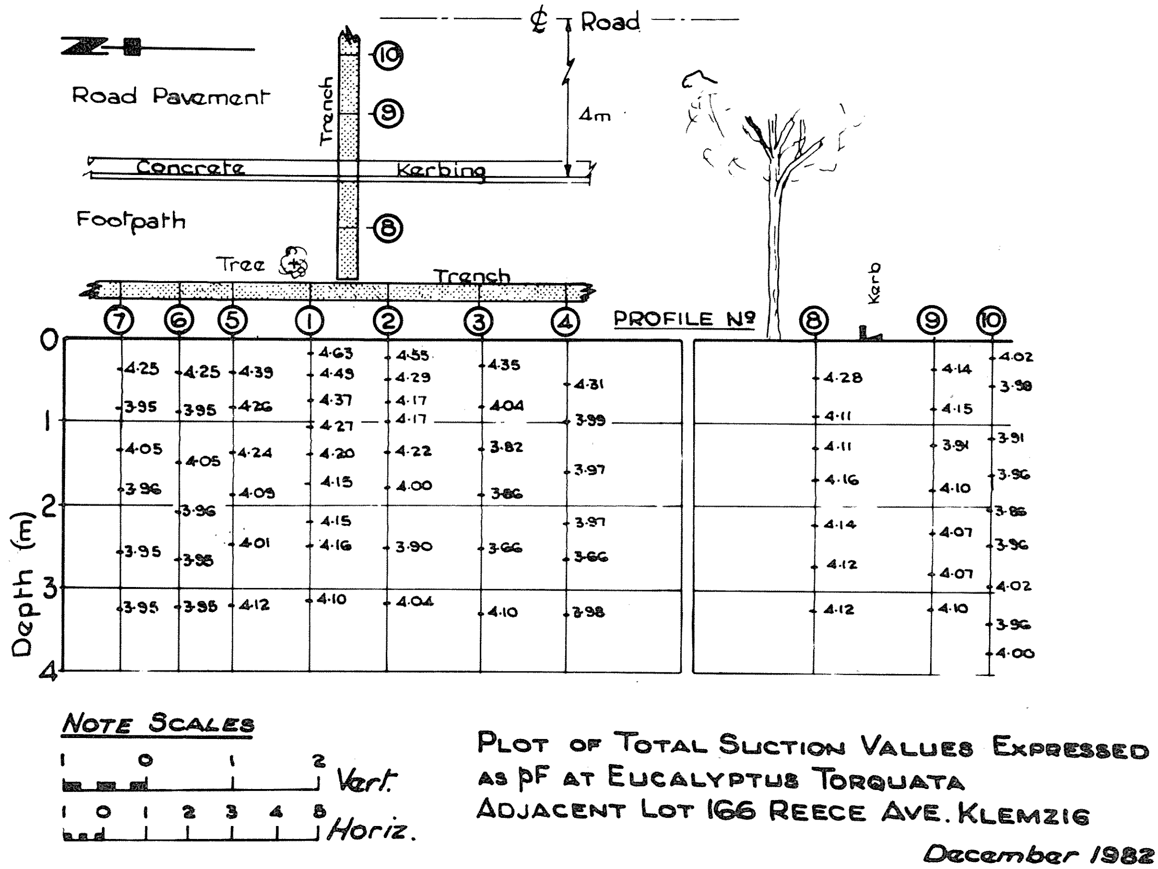

Figure 2 Trenching plan and total suction measurements obtained at Eucalyptus Torquata

Figure 2 shows a plan of the location of trenching with respect to the isolated tree chosen for discussion in this paper. This tree, a Eucalyptus Torquata (Coral Gum) is a common street tree in Adelaide. The tree is approximately 6 m high, is 7 to 8 years old, and healthy.

The kerb adjacent to this tree showed a vertical downward displacement (dishing), observed by stringline, of 25 mm relative to points on the kerb 8 m either side of the tree. Dishing of the kerb and pavement is a regularly appearing feature which is associated with street tree growth in expansive clay areas.

On removal of the soil sample from the side of the trench it was immediately sealed in an air tight bag and returned to the laboratory for testing. Results from a series of total suction measurements are shown at Figure 2. These measurements were carried out using a Wescor psychrometer. A detailed description of the field and laboratory work is given in McInnes et.al.(1983).

The soil suction measurements shown in Figure 2 may be used in conjunction with Instability Index values (refer Richards et.al.(1983)), to estimate the vertical magnitude of the dishing found at this Coral Gum. The analysis for vertical shrinkage carried out compares closely with the measured values of 25 mm.

Benkelman Beam deflection measurements were carried out on the sealed pavement surface alongside the tree. Both inner and outer wheel path alignment deflection values together with the tree's location are shown at Figure 3.

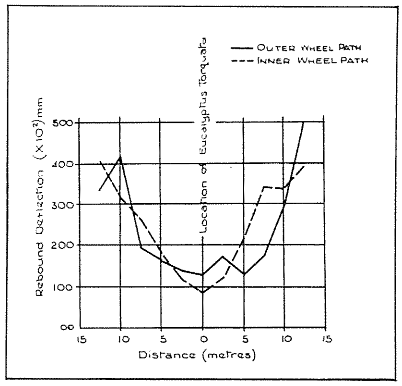

Figure 3 Benkelman Beam deflection measurements on pavement adjacent Eucalyptus Torquata

The symmetry of these deflection measurements about the tree's location is obvious and this may be expected on the basis of the observations and measurements so far reported. A similar pattern has been noticed at other locations on similar soil profiles with a strong correlation between trees and lower deflection values, other factors, such as sub-base/base course thickness being equal. It would appear in this case that the effect of the root system is to maintain the pavement at a drier condition to the extent that over the length of trenching either side of the tree (i.e. 8 m) surface deflection values near the tree are half what they are 8 m away.

The stiffness of the clay subgrade soil over a range of total suction will be controlled by the soil's composition, mineralogy and chemical condition (i.e. soluble salt content and type of dissolved ions in the pore water). If these three factors are unaltered the change in stiffness of the soil with change in total suction may be examined.

To assess the scale of the clay's change in stiffness with total suction a series of unconfined compression tests were carried out on the relatively uniform subgrade soil (Keswick Clay) at the Coral Gum location. Samples for this testing were obtained in 50 mm diameter thin wall tubes from auger holes drilled through the pavement. The initial tangent modulus values from these tests gave some appreciation of the change of modulus measured in the vertical direction with change in suction. A change from pF 3.80 to pF 4.10 (i.e. from 619 kPa to 1235 kPa suction) corresponds very closely to a doubling of the unconfined initial tangent modulus value from 7 MPa to 15 MPa.

4 SUGGESTIONS FOR OVERCOMING THE EFFECT OF TREE DRYING SETTLEMENT

There would appear to be no demonstrated means by which loss of surface shape of a pavement due to nearby tree planting on expansive soil can be avoided. The following suggestions may, however be considered in order to reduce the impact of trees upon a pavement.

- Maintain mature verge vegetation intact throughout reconstruction - this encourages the maintenance of the existing moisture regime within the expansive subgrade.
- Establish new plantings of trees which exert a strong demand for water (e.g. native species) in carefully located groupings and encourage use of trees and shrubs with recognised lower water demand.
- Remove highly expansive, non-uniform soil from upper zones of subgrade to reduce differential movements as moisture varies.
- Install drip feed irrigation so as to maintain moisture balance of soil in vicinity of tree during summer - this technique may be difficult to control to the degree that total suction remains unaltered.

Obviously there are several aspects involved with the above which require field evaluation. The work reported in this paper has indicated that the technology for these evaluations is available. In particular, it should be noted that total suction measurements give a more consistent indication of tree root drying than gravimetric moisture contents.

5 CONCLUSIONS

- In areas of expansive clay, desiccation developed by the root system of a Eucalyptus Torquata (Coral Gum) will cause significant loss of shape of the pavement surface of a residential street.

- The region of drying influence of this species of tree extends throughout a volume of hemispherical shape and radius up to 1½ times the height of the tree.

- The drying influence of a tree can have a significant effect upon the stiffness of the pavement which is reflected as a decrease of surface deflection measurements.

6 ACKNOWLEDGEMENTS

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APPENDIX A

Extract from South Australian Government - Sewerage Act

12.3 Trees Not Permitted in Streets

No person shall plant in any street or road in any drainage area:-

12.3.1 Any of the trees or shrubs listed in schedule "C" to this regulation.

SCHEDULE "C"

Botanical Name	Common Name
Araucaria heterophylla (A. excelsa)	Norfolk Island Pine
Casuarina cunninghamiana	River Oak
Casuarina glauca	Swamp Oak
Eucalyptus bridgesiana (E. stuartiana)	But But
Eucalyptus camaldulensis	River Red Gum
" citriodora	Lemon-scented Gum
" cladocalyx	Sugar Gum
Eucalyptus cornuta	Yate
" maculata	Spotted Gum
" occidentalis	Swamp, Flat-topped Yate
" salmonophloia	Salmon Gum
Ficus - all species	Figs
Fraxinus oxycarpa	Desert or Caucasian Ash
Fraxinus "Raywood" unless grafted or budded on to a root stock of certified Fraxinus ornus (Manna Ash)	Claret Ash
Grevillea robusta	Silky Oak
Lagunaria patersonii	Pyramid Tree
Melia azedarach	White Cedar
Phoenix canariensis	Canary Island Date Palm
Pinus radiata	Radiata Pine
Platanus - all species	Planes
Populus nigra and similar species	Poplars
Robinia pseudacacia	False Acacia, Black Locust
Salix babylonica and similar species	Weeping Willow
Salix chilensis	Chilean Willow
Schinus molie	Pepper Tree
Tamarix aphylla	Athel Tree
Ulmus procera and all deciduous species	Elms