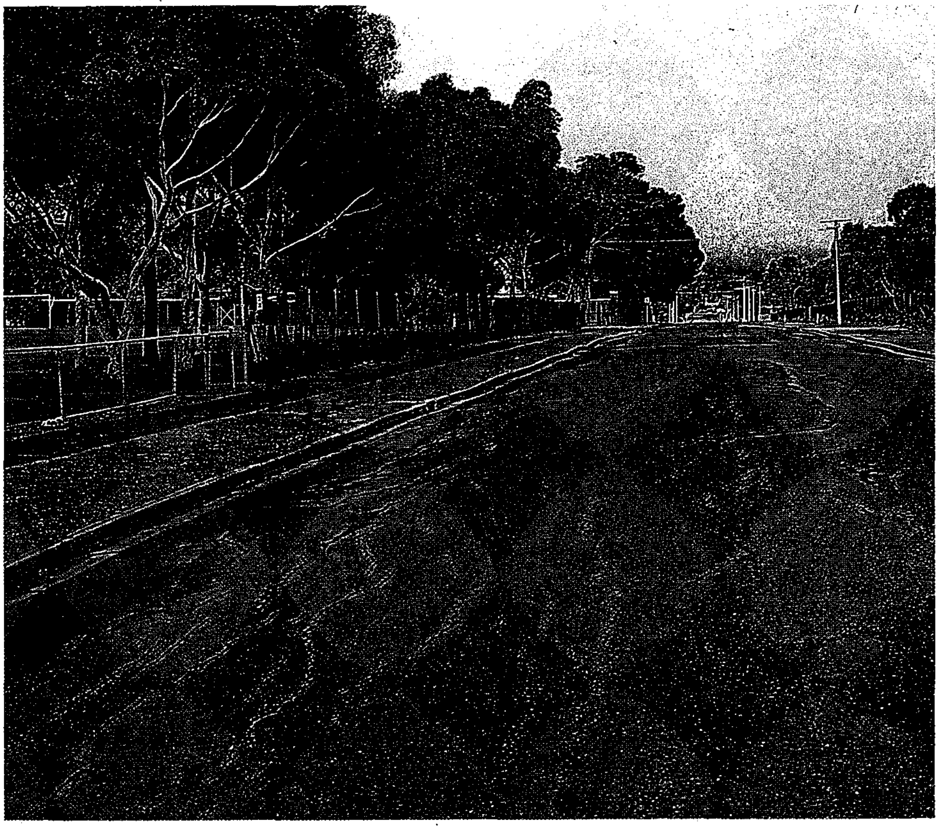
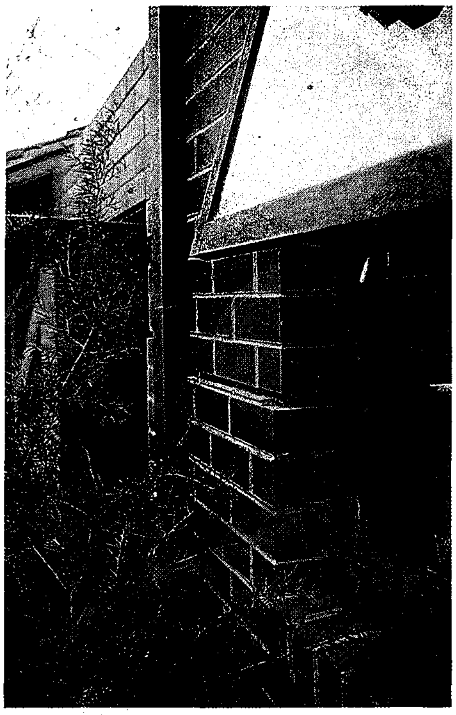


A cracked road in Adelaide. The soil beneath it is a black earth.



A 'tree-damaged' building in the Melbourne suburb of Ringwood. Soil drying has produced shrinkage settlement of the footing.

Soils shrink, trees drink, and houses crack

Each year in Australia, some 50 000 houses crack, accounting for about 80% of all housing insurance claims. Cracking may be caused by defects in building design and materials, or by inappropriate construction techniques. But, most often, soil movement is the cause.

Roughly 20% of Australia is covered with expansive and swelling soils, mostly clays, which expand or shrink as they go through cycles of wetting and drying. The soil types known as black earths and red-brown earths expand and contract more than others.

The CSIRO Division of Soils in Adelaide has been studying expansive soils in the Adelaide area since the late 1940s. Cracking of buildings is a major problem there for two reasons: first, large areas of that city occupy expansive soils (mostly black and red-brown earths); second, many dwellings are solid masonry because of a local timber scarcity, and solid brick houses are more prone to cracking than timber-frame brick-veneer structures.

Added to these factors, over the past few decades the growing population of householders who use sprinklers and drippers on gardens has contributed to waterlogging problems in some districts. Other changes — removal of old trees, planting trees near buildings, increased run-off from paved and covered areas, and burst water pipes and leaking sewerage pipes — have heightened the problem.

Much of the early CSIRO work was based on soil sampling to a depth of 2 m, reaching only the depth of seasonal moisture variation. The Division's soil engineering group led by Mr Brian Richards is now probing further, to depths of 10 m or more to the bedrock. At these depths the researchers can evaluate the effects of tree roots, garden-watering, and broken water pipes, all of which influence the moisture condition of expansive soils below the depth of seasonal moisture change.

Mr Richards points out that two similarly designed houses on the same expansive soil can behave very differently, depending on how the home-owner manages his property. If he plants a line of trees near the house, the soil will subside as moisture is extracted from the foundation. As the house settles, brick walls crack, timber frames distort, and doors and windows jam. If he waters his roses excessively or ignores broken drains and pipes, the soil will heave. This movement, too, can result in cracking.

Cracking of Art Gallery

Not only private houses, but public buildings have become casualties of swelling and shrinking soils. The Division of Soils diagnosed and treated the cracking of the Art Gallery of South Australia. The Gallery — built in the late 1890s — stood intact until the early 1960s, when trees were planted along the eastern wall.

In the late 1960s the Gallery began to fracture, whereupon the CSIRO team headed by Dr Gordon Aitchison drew up profiles of the soil suction (the force with which the soil holds water) at points near and away from the trees. They found that suction was much greater at points near and under the trees than away from them. The soil around the trees had been dried, causing the building to settle.

After the trees were removed a few years later, on advice from the scientists, the ground nearby regained moisture and 'heaved', leading to a partial recovery of the sagging caused by tree roots.

The Division of Soils group is monitoring other public buildings, including schools like Modbury High. This building started to crack in the 1970s, when waterlogging due to excessive garden-watering caused the ground to heave through vertical distances of 6–10 cm. Growth of trees and large shrubs in the last 10 years has reversed the soil water problem: now settlements of up to 15 cm as a result of soil desiccation by thirsty tree roots are causing more damage to the building.

Suction and seasons

Why do clay soils especially shrink and swell and how do trees affect their water content? The amount of water a soil stores depends on the capacity of its particles to hold water. Soils with many small particles of clay hold water with greater force than do sandy soils, so they can hold relatively large amounts of water.

In the semi-arid climate of southern Australia, clay soils undergo seasonal soil moisture changes throughout the top few metres. 'Seasonal heave' is the vertical distance a soil moves from its annual driest state to its wettest. At any soil site, seasonal heave and the depth to which it extends depend mainly on the soil clay type, the soil profile, the weather pattern, and site drainage.

For example, Melbourne has a dry hot summer and wet winter and the subsoils are typically shallow clays. These experience extremes of seasonal moisture change and hence have a substantial seasonal heave. But as the clay layer is generally shallow, the wetting and drying to greater depths caused by garden-watering or trees has little additional effect. Adelaide, on the other hand, sits on deeper clays, and so long-term moisture changes associated with garden-watering, trees, drainage pipes, and so on become more important than seasonal soil water movement.

Desiccation by trees adds to the water loss by seasonal evaporation. A tree acts like a pump, losing almost all of the water taken up by the roots through its leaves. In general, the higher is the total leaf area of the tree, the higher the potential water demand. Researchers in the United Kingdom have estimated that a poplar has an annual water demand of 60 000 litres, while an apple tree needs 20 000 litres per year.

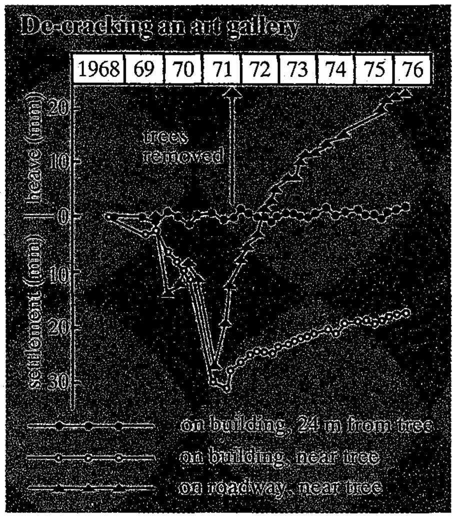
Very little information on water uptake by native trees in Australia exists. From its study of tree-root intrusion into sewers, the South Australian Engineering and Water Supply Department compiled a list of particularly 'thirsty' trees. These included both native and exotic species — a number of eucalypts, plus sheoaks, pines, willows, oaks, and figs.

Mr Richards and two of the Division's researchers, Mr Paul Peter and Dr Bill Emerson, measured changes in total soil suction, in both black and red-brown earths, at various distances from several species of trees in the Adelaide region. They found that, near eucalypts, the total soil suction was significantly higher than under natural grassland.

In the clay underlying black earths, the suction change was less. Nevertheless, the effect of the black earth and the depth of the clay caused much greater soil movement than occurred in the red-brown earths.

By measuring soil suction below various types of trees, the team has been able to

Trees near the South Australian Art Gallery dried out the soil, cracking the Gallery wall. Things improved after the trees were removed.



determine the extent to which different trees control soil moisture. For example, they found that large river red gums caused more desiccation to soil within a 10-metre radius than similarly sized pine trees at the same site. Indeed, all the Australian native species studied used soil water more effectively than did exotic species such as pines, with eucalypts having a greater effect than casuarinas.

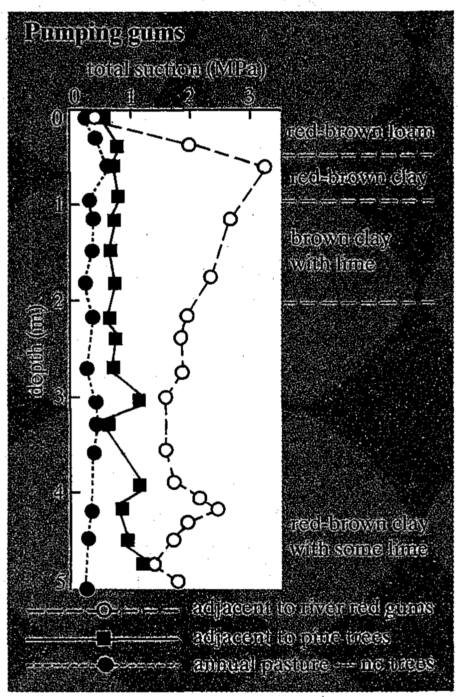
Mr Don Cameron of the CSIRO Division of Building Research in Melbourne has produced guidelines to help home-owners protect their dwellings from damage by trees. The guidelines arose from his observations on damaged houses. Although little evidence about species characteristics is available, some trees are known to cause problems on the average-sized home site. Mr Cameron has provided simple planting rules that vary according to site conditions (such as soil and climate) and the nature of the house. For example, the guidelines recommend that, on a Melbourne clay site supporting a brick veneer house, the home-owner should not plant trees within a distance equal to half the mature height of that species.

For existing tree problems, Mr Cameron suggests soaking the ground using a drip-feed system to prevent the soil from drying out. Pruning tree branches cuts down on water loss through the tree. Choosing the right footing (not foundation, as this term more correctly refers to the soil or rock on which the footing rests) type and stiffness in the first place may permit closer plantings of some trees.

Slab-on-ground

Complementing the Adelaide Division's work on the properties of expansive soils is

Designers are resorting to stiffened rafts as a solution to expansive clay movement.



This graph shows how 'thirsty' river red gums are: they create much more suction than pine trees do.

work on practical design methods for light structures on expansive clays. People like Dr Paul Walsh of the CSIRO Division of Building Research and Dr John Holland from the Swinburne College of Technology have been refining footing designs over the past 12 years and have come up with what has proved to be a successful design strategy.

In Melbourne the need for research into types of building sub-structures developed much later than in Adelaide because most early residential development was on the sands and relatively stable clays, overlain by silt and sand, of the eastern suburbs. With increased development on the expansive basaltic clays in the western suburbs, new building problems arose, as a result of soil shrinkage.

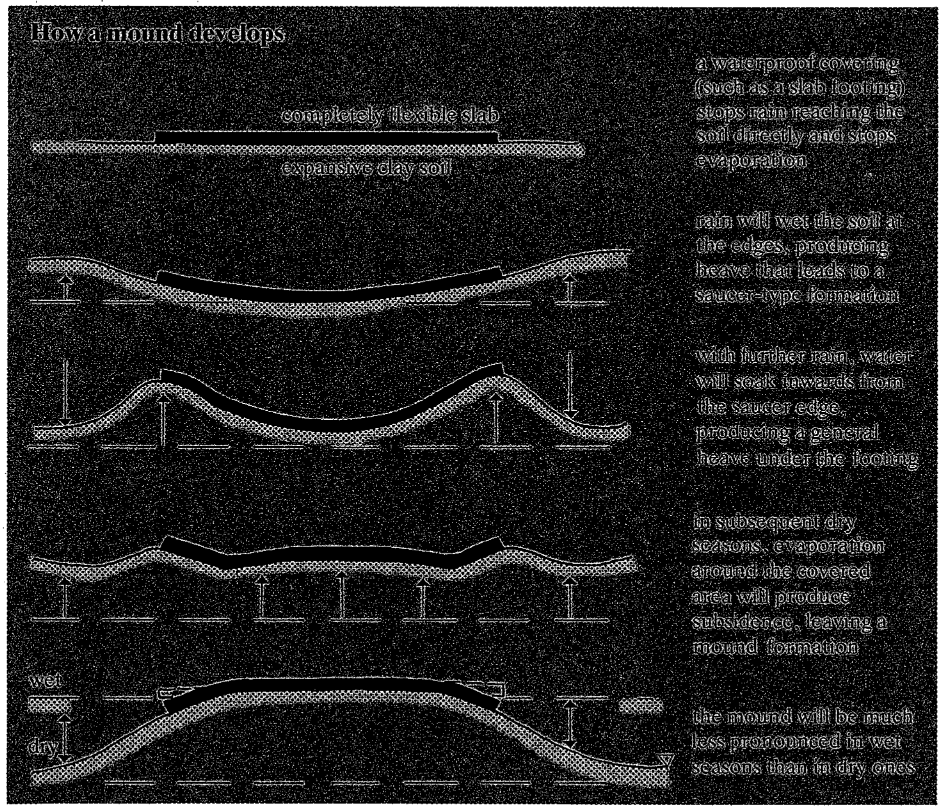
In 1970, Dr Bob Lytton, working at the then CSIRO Division of Applied Geomechanics, developed the 'beam-on-mound' design theory for strip and slab footings on expansive clays. With this method Dr Lytton could calculate the soil movement and deflections in footing structure by using mathematical relations between mound deflection and beam stiffness.

Dr Walsh later modified the 'beam-on-mound' model by substituting flexible rather than rigid beams on the dish or mound. He then developed a formula for finding the correct stiffness of beam that allowed for heaving or subsidence. This would enable designers to estimate how strong the concrete footing or slab should be.

The results of extensive mathematical modelling and of field tests around Melbourne enabled Dr Walsh and Dr Holland to develop simple standard slab designs for unstable and moderately expansive clays. For extremely 'shrinkable' sites, they specify deeper stiffer footings or a lightly stiffened raft, which is simply a concrete floor with beams built in to resist movement.

Dr Walsh and Dr Holland have developed a simple soil classification system for Melbourne soils and have recommended footing types for each soil grade (stable, intermediate, and unstable). Their system has been incorporated into the Victorian Uniform Building Regulations.

In 1982–83 Dr Walsh and Mr Cameron conducted a survey to find out more about footing performance for single-storey detached houses in Queensland, New South Wales, and Victoria. Except for Victoria, the answers from building surveyors and consultants revealed that the most common causes of footing failure were inadequate



By observing mound development and movement in expansive soils, scientists at the Division of Building Research developed a formula for working out how stiff concrete slab footings need to be.

site investigation and poor selection of footing system, particularly the use of light strip footings on highly expansive clays. But Victorian building surveyors felt that the most common problems were owner-induced — that is, overwatering of gardens, neglect of plumbing leaks and drains, and so on.

Those surveyed considered that the stiffened raft foundations recommended by the Division of Building Research provided the best solution to the problem of expansive soils.

Performance surveys carried out by the Division show that concrete slab-on-ground floors perform better than conventional footings in the clay soils of Melbourne because they are stiffer and less prone to rotational movements. In Adelaide, designers are increasingly resorting to stiffened rafts as a solution to expansive clay movements.

Apart from Melbourne and Adelaide, what of the other 20% of the country with shrinking soils? In outback New South Wales and parts of Victoria, deep black earth deposits can cause large vertical movements in buildings — jammed doors and windows are a common domestic irritation. Some deep grey and black earths near Ipswich and Toowoomba in Queensland produce similar structural problems.

Perth is sitting pretty with little fear of clay feet — most of the city is built on stable sandy soil. In Sydney, most of the older buildings are also sited on stable soils, overlying sandstone.

However, buildings recently constructed on the deeper, expansive clay soils of Sydney's western suburbs are more at risk. Sydney is not subject to extreme summer drying, but its soil can be vulnerable to longer-term drying cycles caused by occasional droughts.

The 1982–83 drought caused about $1 million damage to buildings constructed on the very light strip footings typical of the city. Most of the damage was minor. Dr Walsh feels that requiring the use of very deep footings or strongly stiffened rafts may not be justified there, as soil-related building damage occurs rarely.

Mary Lou Considine

More about the topic

The effect of vegetation on the swelling and shrinking of soils in Australia. B.G. Richards, P. Peter, and W.W. Emerson. *Geotechnique*, 1983, **33**, 127–39.

Residential foundation practice in eastern Australia. D.A. Cameron, P.F. Walsh, L.B. Budgen, and R.I. McNamara. *Papers, Australian Institute of Building Surveyors, First National Conference, Perth, September 1983.*

Footings for houses on cohesive soils. P.F. Walsh. *Papers, Australian Institute of Building Surveyors, Sixth State Conference, Surfer's Paradise, August 1982.*