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Trees and Buildings

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Please note

Trees are most desirable features of the environment of buildings, adding their own special beauty to any urban scene. The welcome shade they provide in high summer has long been a recurring theme of writers. It is always regrettable when they have to be cut down to make way for new buildings, even though this is frequently unavoidable. The planting of new trees, on the other hand, is one of the most welcome subsidiary aspects of urban development and redevelopment, and the old saying that one of the happiest sights in the world is an old man planting a new tree is no mere figure of speech but a timely reminder of the living character of trees, on a time scale comparable with that of human life.

The growing of trees is therefore, a necessary complement of building, chiefly for aesthetic reasons, but with at least some utilitarian value. The extent to which modern buildings still depend upon the materials derived from trees is widely recognized, but the further aesthetic association of trees and buildings is all too often taken for granted. To some it may be surprising to find a Digest devoted to the subject, so little attention does it normally receive. Others, however, will appreciate why *Trees and Buildings* are to be discussed, and can anticipate what is to be said if they have had the misfortune to encounter the problems that can sometimes arise when trees are planted too close to building foundations.

The Problem

It is the purpose of this Digest to explain the problem to suggest how it can be avoided, and to outline remedial methods to correct damage that trees may have caused. For serious damage can result from the encroachment of roots into the immediate environment of foundations if the local soil is one that is susceptible to swelling or, more particularly, to shrinking with change in moisture content. Since trees are living organisms, they need water for their continued existence and to support their natural growth. If they cannot get their necessary supply from rainfall, their root systems will try to draw water from the soil in which they grow. If this water is abstracted from a soil that is volumetrically susceptible to moisture change, soil shrinkage may result, with serious structural complications leading at the least to the unsightly cracking of a building superstructure if not, indeed, to more serious damage.

Trees and their Roots

About 10 per cent of the wood mass of a tree is to be found under the ground surface in the form of roots, which extend quite surprising distances. The total length of all the roots of a large oak tree, for example. will be several hundreds of miles. The functions of the roots are not only to provide anchorage in the ground for the tree, but, more importantly to obtain and provide the minerals and water necessary for its well-being. If normal sources of water adjacent to the tree dry up, the root system will spread in a remarkable effort to discover alternative supplies. As an extreme example, it is on record that tamarisk roots were found 100 feet below ground surface when the Suez Canal was excavated. In more recent studies. there are many cases in which roots of common deciduous trees have been traced through horizontal distances of over 100 feet from the trees of which they were a part.

These immense root systems are necessary because of the vast quantities of water used during the (summer) growing season. Water is contained in all the tissues, both dead and alive. Young leaves may contain up to 90 per cent of water; and even tree trunks contain as much as 50 per cent. But although the formation of 100 grams of cellulose requires 55 grams of water, a tree will lose correspondingly by transpiration almost 100,000 grams of water, or one thousand times as much as its gain in weight.

It is this dramatic process of transpiration activated by solar energy, that is responsible for drawing water from the root system to the topmost leaf of the tallest tree, as high as 350 feet above the ground in the case of California redwoods. The process is automatically controlled by nature. For each type of tree a certain amount of water is regularly required for transpiration and, to a minor degree, for tree building. It is this insistent demand that causes the spread of root systems when normal water supply is reduced.

It is from rainfall that trees get their vital water supply, rainfall after it has soaked into the surface of the ground and so become available to the root system near the ground surface and immediately around the tree. In all districts, however, variations in annual rainfall always occur. In occasional years, the variation may be so great that there is common talk of "a dry year." In Ottawa, for example, the total rainfall during June and July 1955 was less than 2 1/2 inches, as compared with the long-time annual average of 7 inches. And when dry years do occur the root systems of trees will spread in a search for the water so essential to the life of the tree. If this happens in a sandy soil, no effects may be noticed at the ground surface. If, however, the local soil is a clay that is influenced by changes in moisture content, then the abstraction of water from the voids in the soil will lead to a shrinkage in its volume, with consequent settlement of the ground surface.

Critical Soil Types

Important areas of southern Canada are underlain by clays that are affected in this way, so that the problem created by the presence of trees adjacent to buildings is a very real one for Canadian architects, engineers and builders. The soil underlying much of the Prairies is a clay that has the dual distinction of shrinking with decrease of moisture content below its natural value and of expanding if the moisture content is increased above this value.

The great industrial area of the St. Lawrence and Ottawa Valleys has as its subsoil an unusual type of clay (commonly called *Leda Clay*) that derives some of its properties from the fact that it was deposited by settlement in sea water when the area was submerged, in glacial time, beneath what is known as the Champlain Sea. Its natural moisture content is often quite high. Because of the way in which the minute soil particles are arranged as a result of its formation, it has a quite remarkable - and unfortunate - shrinkage potential.

The process is not fully reversible and rewetting the soil after shrinkage will not usually restore it to its original volume. This compounds the practical problem since, if serious surface settlements do occur due to the shrinkage of Leda Clay, restoration of the original moisture content of the soil may not bring the ground back to its original level.

Fortunately, these critical soil types can be readily detected by simple soil tests carried out upon samples obtained from test borings put down in advance of construction. It is therefore, always possible to predict the possibility of trouble with these soils and to prepare the design of foundations and landscaping in such a way as to obviate trouble after the building has been erected.

Some Examples

To those readers who have not experienced trouble with foundations on clay soils caused by trees, the foregoing discussion may appear to be somewhat theoretical. Before presenting any further general comments, therefore, some practical, possibly mundane, examples will be briefly recorded.

In order to have available actual figures for just such a purpose as this (and for other research reasons) DBR/NRC carried out a few years ago some detailed observations of ground movements near a row of medium sized elm trees immediately adjacent to the Building Research Centre in Ottawa. The single row of trees averaged 55 feet in height; they are growing in Leda Clay, the depth to bedrock being beyond all possible influence from the surface.

Groundwater level was close to the surface at the start of the summer but receded as the year progressed. It was a "dry summer" with considerably less rain than usual, so that the observations made may be regarded as typical of what does happen in the vicinity of elm trees growing in the Leda Clay in the St. Lawrence and Ottawa Valleys when rainfall does not satisfy the water demand.

By levelling well-secured observation points against a fixed deep benchmark, soil movements around the trees to depths of 14 feet and to distances up to 50 feet were observed throughout the summer. It was found that even at a depth below the surface of 13 feet, and at a distance of 20 feet from the row of trees, a vertical settlement of ½ inch took place. Surface settlements ranged from over 3 inches at the trees to ½ inch almost 50 feet away. At a depth of 5 feet, a common depth for house foundations in the Ottawa district, the settlements varied from a maximum of 2¼ inches 5 feet away from the trees to ¾ inch 30 feet away.

The older part of Ottawa is known to many as a "city of trees." It is not surprising to find that, beautiful as are the rows of large trees to be found (for example) along O'Connor and Metcalfe Streets, and particularly on the shorter cross streets in this part of central Ottawa they have made their presence all too evident by cracks in the older residential buildings in this area.

A survey of 574 buildings showed differential settlements, in the same building, varying up to 14 inches. The consequent cracking and tilting of windows and doorways can well be imagined. In every case of serious settlement large trees were growing nearby in the open garden areas that (fortunately) are still to be found here. The correlations obtained throughout the survey between the presence of trees and the settlement and associated cracking of buildings left no possibility of doubt that the trees were responsible. Any visitor to Ottawa who walks along one of the streets mentioned can see vivid evidence of the effect of trees by merely looking at the undulations in the sidewalks and noticing the "culprit trees" nearby.

[Would the reader kindly turn back and read the opening paragraph so that he will realize with what regret the presence of trees has thus to be indicted. If he will read on, he will see what can be done to combine the beauty of trees and the stability of foundations.]

Ottawa is not peculiar in this respect. Similar settlements adjacent to trees are to be seen in Montreal and in many other urban areas in the St. Lawrence and Ottawa Valleys where Leda Clay is the underlying subsoil. In the cities of western Canada the same phenomenon is to be observed where the local soil is a variety of the peculiar clays of the Prairies. To single out any location for special mention would be to make invidious comparisons, but it can at least be recorded, with all due anonymity, that there is a small town in Saskatchewan in which the ground settlements will probably one day be internationally famous in the annals of soil mechanics.

The problem is not confined to Canada. There are well authenticated records from Africa, Australia, Belgium, Burma, China, India, Palestine, the Sudan and from Texas. Some of the most valuable have come from soil mechanics workers in Great Britain. Typical of British examples are houses so badly cracked due to soil shrinkage that their corners had to be shored up, the troubles being caused by Lombardy poplar trees within 20 feet of one house, and a combination of oak trees and young poplars 35 feet away from another. A completely uncracked wing of a four-storey block of flats was found to have separated from the adjoining block by as much as 2 inches due to the effect of elm trees.

Remedial Measures

The record could be continued but enough has probably been said to show that in areas where the local soil is a clay that shrinks (or swells) with change in its moisture content some cracking of masonry buildings, and especially of smaller masonry structures, may be due to the presence of trees growing too close to the buildings. If cracks develop or increase at the end of a very dry period, the probability can be regarded almost as a certainty.

In all but minor cases a soil expert should be consulted, if only to confirm that the trouble is indeed due to the presence of trees. If the trouble has developed at the end of an exceptionally dry period, extensive watering of the ground around the trees may effect a restoration of the soil to something like its original condition and the cracks may close. Future watering in dry periods can then give a reasonably permanent solution. [When this advice was first given by DBR/NRC, the sanity of the staff was questioned; leaving a garden hose turned on over a long weekend led to the substantial closing of a 1¼ inch crack in a new brick building.]

When cracking in a building can be definitely linked with the presence of adjacent trees, especially poplars, other than during real drought, and especially if they have been planted very close to a building, then the only solution is to cut down the offending trees and to remove as much as possible of the main root system.

Preventive Measures

Such destruction of living trees is always regrettable, even though occasionally essential, especially since trouble might have been avoided by more care in the original planning. Local experience can here be helpful, but only when gained from sound practitioners who are themselves fully conversant with the effect of trees upon clay soils.

The following may be regarded as essential requirements in all such preliminary work.

1. Accurate knowledge of soil conditions at the building site *must* be procured, and by a proper soil survey for all larger buildings. If the soils that will support the foundation are not influenced volumetrically by change in moisture content, problems with trees need not be anticipated; but if they are, then foundation and landscaping design must be adjusted accordingly.
2. Shrinkable clays bring into foundation design problems other than those caused by trees, since soil moisture content can be influenced by many other factors. Precautions as to the depth of the foundation below ground level and the necessary rigidity of the foundation itself, as incorporated in the design of an experienced foundation engineer, will therefore usually serve this dual purpose.
3. If trees are already growing on the building site, every effort should be made so to locate the structure that it conforms with the suggestions in the next paragraph. If this cannot be done then, with natural reluctance trees that are going to be too close to the building must be cut down and their root systems removed. It is far better that this should be done and new trees planted appropriately than that aesthetic claims should over-rule sound judgement with the possibility of damage to the building and the eventual inevitable removal of the trees in any case. Care should be taken that the removed trees have not already desiccated the clay, which may then swell under the changed environment.
4. If trees are to be planted as a part of the landscaping around the building, a good working rule has been found to be that trees should preferably be planted no nearer a building on shrinkable clay than the eventual height to which the tree may be expected to grow. This rule may require modification if the topography around the building varies. Even in its application, attention must be given to the differing transpiration characteristics of trees.

This Digest may therefore well conclude with a list (from a paper by Ward[1]) of the more common trees in order of *decreasing* water demand, and so of *decreasing* trouble-potential:

Poplar	
Alder	
Aspen	
Willow	
Elm	
Maple	
Birch	
Ash	
Beech	
Oak	Broad leaved deciduous
Larch	Deciduous conifer
Spruce	
Fir	
Pine	Evergreen conifers

1. Ward, W. H., "The Effects of Fast Growing Trees and Shrubs on Shallow Foundations," Jour. Inst. Landscape Architects, p. 3-12, April 1947.