POST-CONSTRUCTION EFFECTS OF PRE-EXISTING TREES

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Abstract

Active soils expand and contract due to changes in soil moisture. Trees, particularly species of mesquite and oak native to Texas, can desiccate the soils to considerable depths. Once these trees are removed, it can take years for the soils to re-hydrate and establish equilibrium with the surrounding soils. During the re-wetting process, shallow foundations and ground-supported floor slabs placed over desiccated soils can experience significant differential movement and subsequent distress. Case studies indicate the differential movement can approach the magnitude of total heave.

Using case studies, the influence of pre-existing trees on building construction is illustrated. These effects can be identified and quantified using results obtained from aerial surveys, soil suction and pocket penetrometer tests. Early recognition and evaluation of the potential for differential movement may justify increasing the foundation stiffness or modification of the soil to reduce the potential for distress.

Introduction

Geotechnical investigations often overlook the localized effects that pre-existing vegetation can have on soil suction and thereby potential heave. Extensive review of geotechnical reports for residential developments within the Dallas/Fort Worth metroplex indicates the engineering community rarely, if ever, address the effects of pre-existing vegetation.

Numerous publications discuss the qualitative effect of vegetation, to include the Post-Tensioning Institute's "Design and Construction of Post-Tensioned Slabs-on-Ground" (1980). This publication notes that pre-existing vegetation is one of the major factors affecting soil design parameters not related to climate.

Various researchers have also attempted to quantify the affect of vegetation on soil movement. Biddle (1984) studied the effects of 36 species of trees in southern England for a period in excess of four years. Research results demonstrated that the type of clay makes little difference on the drying pattern of the tree. Results also showed that differences between individual trees of the same species are small unless there are differences in the soil conditions. Biddle's results indicate that the tree species within the study can desiccate soils to depths of 5 to 10 feet in the immediate vicinity of the tree and that the drying effects can extend

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horizontally 0.8 to 1.8 times the tree height. Typical results reported by Biddle are shown in Figure 1.

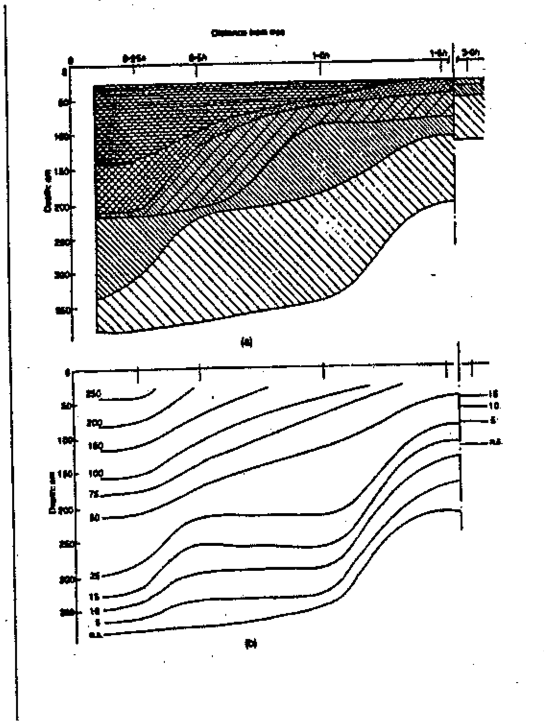

Figure 1. Drying Effects of Poplar (Biddle)
(a) soil moisture reduction, (b) moisture deficit (mm)

The zone of influence is dependent upon the climatic condition with desiccation effects becoming more pronounced during periods of drought. Drying effects can last for several years after trees are removed. Driscoll (1984) reported on studies performed by Samuels and Chaney in 1975 that indicated the effect of pre-existing elm trees on a lightly loaded, ground-supported foundation with 44-inch deep strip footings. Total observed movements over a 20-year period were close to 4 inches. A subsurface investigation showed that the trees had desiccated the soils to a depth of almost 16 feet.

Typical construction for residential development requires the removal of pre-existing trees resulting in pockets of dry soils where the trees once stood. The potential for heave is greater in these desiccated areas. Due to the variation in local moisture conditions, the potential for differential heave is also increased. In most cases, sufficient time is not allowed for the soils to re-hydrate after tree removal.

The purpose of this paper is to acquaint engineers with available technology to identify and quantify the influence of vegetation on the potential and magnitude of differential movement. The following sections present information from a study of the influence of a lone tree on soil moisture and suction and two case studies. The case studies document the magnitude and effect of differential movement on ground-supported foundations and "floating" floor slabs and cost of repairs.

Evaluation of Effect of Isolated Trees

An investigation on the effects of pre-existing trees on soil moisture, and thus soil suction and potential vertical movements (PVM), was undertaken in Grand Prairie, Texas. The field portion of the study was conducted in April, 1996. The purpose of this investigation was to evaluate if relatively inexpensive methods could be used to detect the influence of the vegetation.

Geologic conditions consist of alluvial soils over shale of the Eagle Ford Formation. The material types, sequence and properties are summarized in Table 1.

TABLE 1
SUMMARY OF SOIL PROPERTIES

Soil Description	Depth, ft.	Liquid Limit	Plastic Limit	Plasticity Index
Dark Gray grading to yellowish brown CH clay	0 to 9	50 to 55	20 to 25	25 to 35
Yellowish brown CL sandy clay	9 to 19	35 to 45	15 to 20	20 to 25

The site consisted of a 3-inch thick asphaltic-concrete paved parking lot. The pavement had been in-place for more than 25 years. A live oak tree located in an isolated landscape island was selected for study. The tree was approximately 30 feet in height and 16 inches in diameter.

Three, 20-foot deep borings were drilled at the locations shown in Figure 2. Borings were continuously sampled using three-inch diameter Shelby tubes. All samples were tested for consistency using a pocket penetrometer. Soil moisture content (ASTM D-2216) and total soil suction (ASTM D-5278) tests were conducted on each sample. Atterberg limits (ASTM D-4318) were conducted on selected samples.

Pocket penetrometer, soil suction, and soil moisture content test results versus depth are presented graphically in Figures 3 through 5. The drying effect of the tree is most pronounced by analysis of the consistency (or stiffness) measured using the pocket penetrometer (Figure 3) and

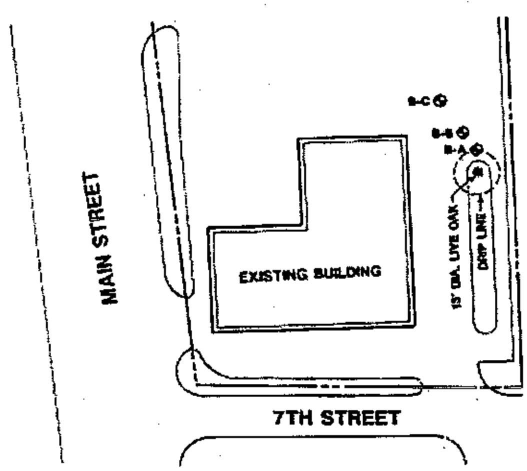

Figure 2. Plan of Borings

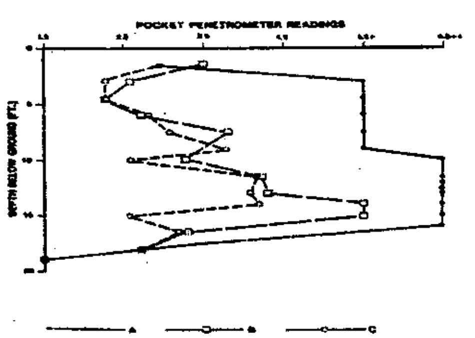

Figure 3. Variation in Consistency w/Depth

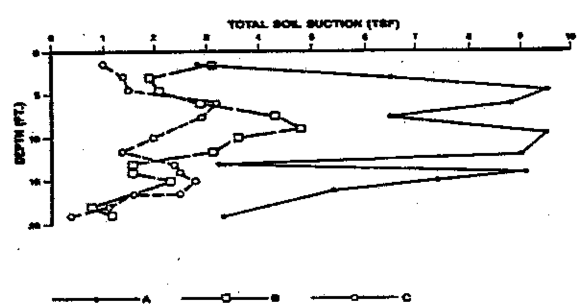

Figure 4. Variation in Suction w/ Depth

analysis of total suction (Figure 4). This variation is not observable by comparison of soil moisture (Figure 5) alone.

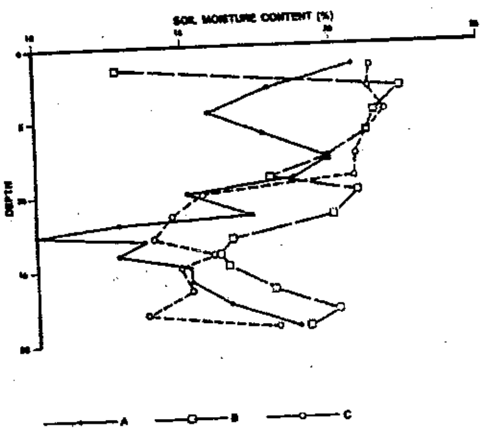

Figure 5. Variation in Moisture w/ Depth

Tests indicate dry and very stiff to hard soils within the drip line of the tree, with decrease in suction (and thus potential swell) with increased distance from the tree. Analysis also indicates that for a paved site, the horizontal influence of the tree is on the order of the height of the tree.

Various methods are available for prediction of potential movement. However, all of the methods would intuitively produce a greater potential for heave in dry conditions than for moist or saturated soils. With the measured variation, as shown in Figure 4, a greater potential for differential movement over relatively short distances exists on sites where vegetation exists prior to construction.

Case Studies

Case 1 - The first case study involves distress of two residences (808 Craig Drive and 829 Schade Trail) located in Mesquite, Texas. Foundations for both homes consisted of post-tensioned slabs. An aerial photograph of the homes and area is provided in Figure 6.

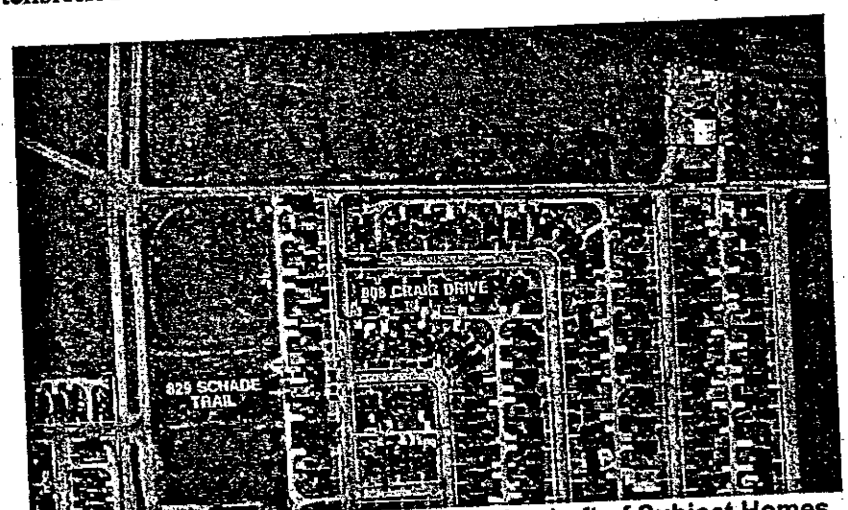

Figure 6. Site Conditions. Note Tree Line Left of Subject Homes

In general, foundations within the subdivision have reportedly performed satisfactorily, with the exception of the homes within the immediate vicinity of the subject properties. The home on the west corner of Craig had also experienced differential movement but was not investigated.

Distress consisted of differential movement in the "edge lift" mode. Differential movements of 5-1/2 and 7-1/4 inches were measured in the two homes. The typical pattern of movement determined by elevation survey is shown in Figure 7.

Based on experience, the observed differential movement would likely be due to:

- differential settlement of fill
- differential wetting or drying of the upper soils attributed to point sources or sinks
- variation in subsurface conditions (i.e., material types)
- variation in the potential movement of the upper soils at the time of construction, coupled with post-construction wetting of the drier soils.

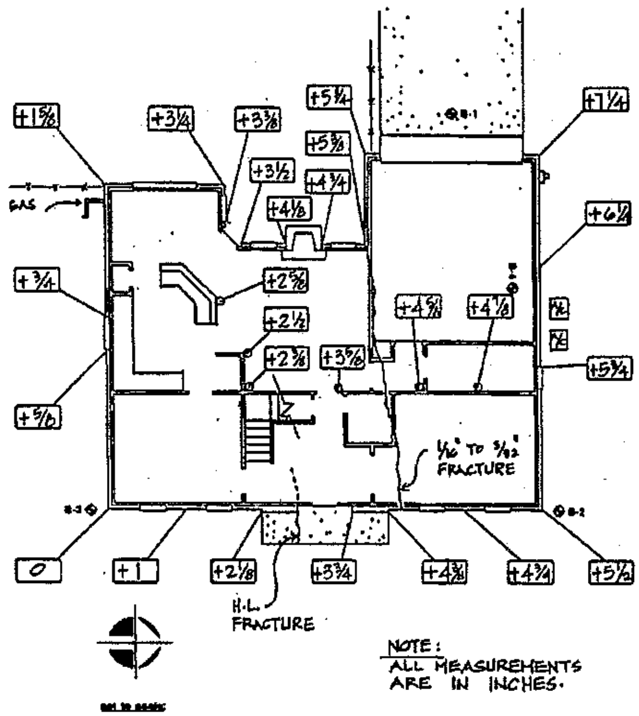

Figure 7. Differential Elevations, 829 Schade

Initial investigation consisted of drilling and testing sample borings around the perimeter of the homes. Samples obtained were subjected to moisture content, total soil suction and pressure swell tests.

Space limitations restrict discussion of both residences. A brief description of procedures and findings for 829 Schade Trail are presented below.

The relative foundation elevation survey for 829 Schade Trail is shown in Figure 7. The home experienced over 7-1/4 inches of differential movement during a two-year period, with the northwest corner experiencing the greatest distress and movement.

Four borings were drilled at locations shown in Figure 7. Borings B-1 and B-4 were drilled in areas that had experienced the greatest amount of movement. Boring B-2 was drilled in an area that had experienced a moderate amount of movement. Boring B-3 was drilled where little or no movement was indicated by the survey.

Subsurface conditions consisted of residual CH clays over weathered shale. The clays extended to depths of 9-1/2 to 13 feet where weathered shale was encountered. Material descriptions and classification data are presented in Table 2.

TABLE 2 SUMMARY OF SOIL PROPERTIES				
Soil Description	**Depth, ft.**	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**
Dark brown to grayish-brown clay fill	0 to 4	40 to 50	15 to 20	20 to 30
dark brown to grayish-brown CH clay	0 to 8	50 to 55	20 to 25	30 to 35
light gray to brownish-yellow CH/CL clay	7 to 13	40 to 50	15 to 20	30 to 35
gray and brownish-yellow, weathered shale	10 to 43	65 to 75	20 to 25	45 to 55

Based on pocket penetrometer and suction results, the upper clays were relatively moist to depths of 13 to 14 feet. Plots of total suction versus depth for Locations B-1 and B-3 are provided in Figure 8.

Settlement of fill along the south wall was not considered likely. First, the amount of fill was limited to less than three feet and perimeter beams extended to greater than two feet. Secondly, borings indicated the fill was stiff to very stiff and of limited lateral extent. This decision was also based on the observation that the majority of the distress occurred along the north side of the residence, with little or no damage along the south wall.

Based on the post-construction measured suction, moisture and soil consistency as measured using the pocket penetrometer, the condition of the soil and weathered shale appear to have been relatively uniform. This condition would not explain the observed differential movement unless significant variation in moisture (i.e., potential swell) existed at the time of construction.

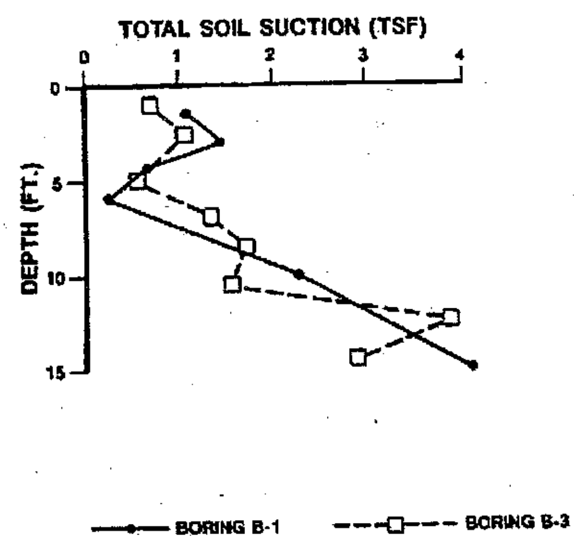

Figure 8. Comparison of Suction Values across Foundation

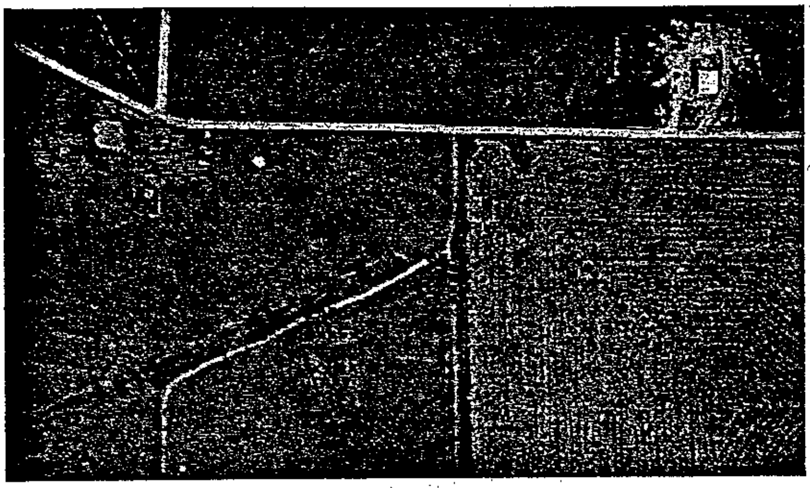

Figure 9. Conditions Prior to Construction

Similar conditions were encountered at 808 Craig. It was therefore decided to obtain aerial photographs of the site prior to construction to ascertain if pre-construction conditions may have existed which would have resulted in localized variation in soil moisture. The pre-construction site conditions are shown in Figure 9.

As shown in Figure 9, a tree line was present across the northwest corner of the subdivision prior to construction. The site was cleared in 1987. The home at 829 Schade was built after March, 1991. The second house, 808 Craig, was constructed in the summer and fall of 1990. Comparison of Figures 6 and 9 indicate direct correlation between the direction of differential movement and the location of the tree line existing prior to construction.

Case 2 - Case 2 involves construction of a tilt-wall warehouse with a ground-supported floor slab. The warehouse is located over alluvial deposits overlying the Eagle Ford Formation. The initial geotechnical investigation was done in May of 1994, and indicated 10 to 13 feet of clay and sandy clay over weathered shale. The clays had LL of 30 to 50 and PI of 20 to 30. Pocket penetrometer, moisture content determinations and soil suction tests indicated the upper soils to be dry.

Several pecan trees were growing across the site, particularly at the north corner. The trees within the building footprint were removed. The soils engineer recommended preswelling the pad using pressure injection, and construction of a perimeter root barrier extending to a depth of four feet. The floor slab was placed in September, 1994.

By September, 1995, the floor slab in the north corner of the building had developed a center lift condition with differential movement of approximately 1 to 1-1/2 inches. Foundation elevation surveys conducted in July and September of 1995 indicated the north corner of the floor slab was undergoing heave. The measured differential movement of the slab is provided in Figure 10. A study was conducted to evaluate the cause of movement, potential for future distress, and remediation methods.

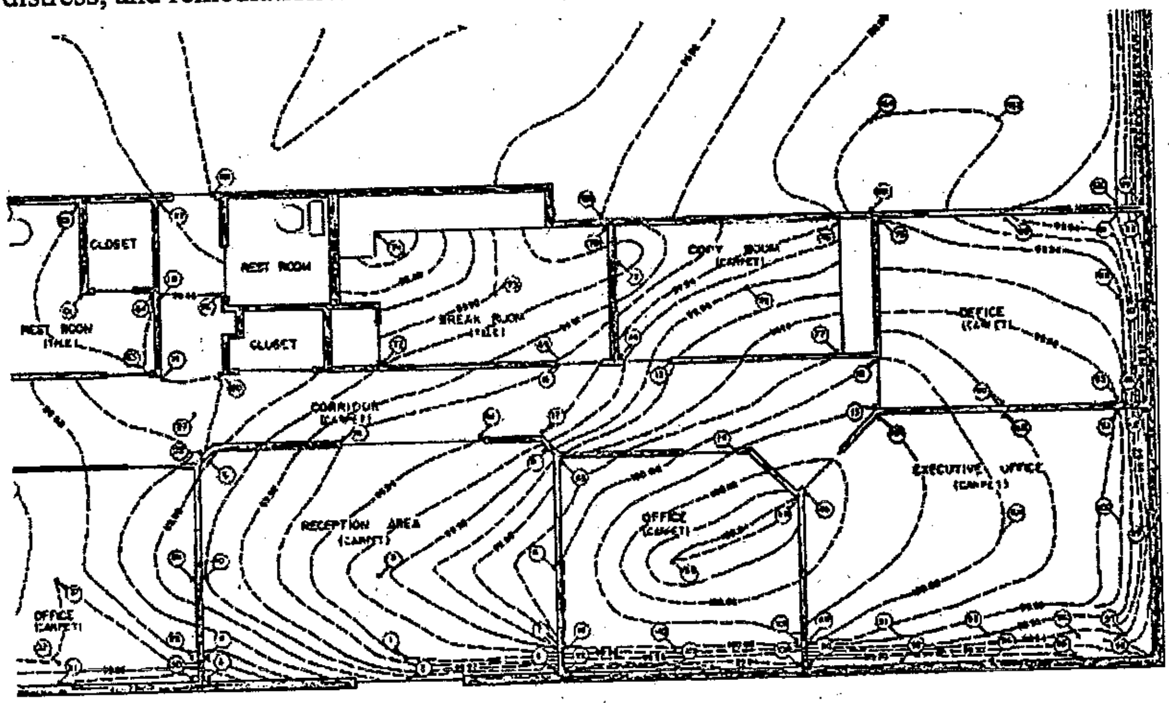

Figure 10. Measured Differential Movement, Inches (Contours at 0.01 Intervals)

Analysis of post-injection borings drilled prior to construction of the slab indicate the soils within the northwest corner of the structure were relatively dry at completion of injection. Because of time constraints, belief that a one-inch potential movement was acceptable, and the proposed construction of a root barrier, no additional injection in this area was performed.

Three borings were drilled in the area of the north corner to evaluate soil moisture conditions. Pocket penetrometer and soil suction results indicated the underlying soils in the northwest corner to be moist to depths of 9 to 11 feet. Results of pocket penetrometer tests conducted on samples from post-injection and post-movement borings drilled in the northwest corner versus depth are shown in Figure 11.

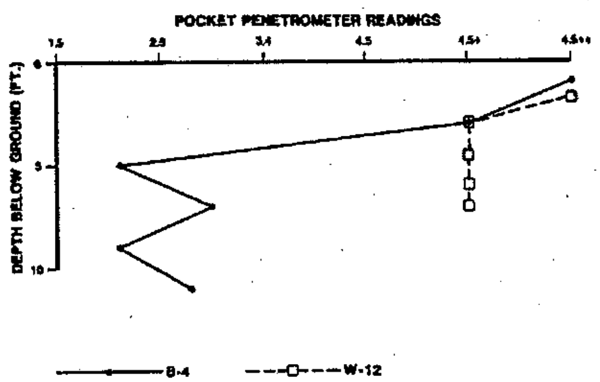

Figure 11. Comparison of Pocket Penetrometer Values (W-12 drilled prior to construction of slab)

Potential vertical movements were calculated using TxDOT Method 124E for dry conditions extending to a depth of 10 feet. Calculations indicate that approximately one inch of movement would occur from a dry initial condition.

Remediation consisted of removal and replacement of the affected area of the slab. Approximately 1,015 square feet was demolished. Costs for replacement of the slab and affected furnishings was approximately $31,300.00.

As in the first case study, the soils would have been dry prior to constructing the floor slab for heave to have occurred. The likely cause of desiccation was the pre-existing tree located on the northwest corner of the building. Comparison of pocket penetrometer tests from post-injection and post-distress borings confirm a decrease in consistency indicating heave or swelling of the supporting soils.

Conclusions

The case studies illustrate the potential effects of pre-existing trees on the behavior of expansive soils. The desiccation caused by trees results in differential movements that can equal the total potential vertical movements for a site. Ground-supported foundations and floor slabs constructed over dry soils can be damaged as a result of post-construction wetting and subsequent differential movements.

Relatively simple laboratory testing consisting of evaluation of soil consistency by use of the pocket penetrometer and conduction of soil suction tests can aid in identifying the potential for differential heave. Aerial photographs can also aid in evaluation of the potential for isolated trees or tree groups.

The tree study reported herein demonstrates that trees can desiccate soils to depths of 13 to 14 feet. The case studies also show that differential movements and subsequent damage can occur within 1 to upwards of 5 years after construction.

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