Field measurement of edge moisture variation distance

Les mesures in-situ de la variation dans la largeur affectée par l'humidité du bord

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SYNOPSIS: Soil suction and surface elevation measurements are used to determine the edge moisture variation distance occurring beneath the perimeter of a surface cover in an arid climate. The edge moisture variation distance determined from these measurements is compared to an edge moisture variation distance vs. climate relationship predicted from structural backcalculations and was found to compare reasonably well for edge lift heave conditions for this arid climate test site. The results from this comparison suggest that at least the arid climate edge lift heave condition prediction curve is valid.

INTRODUCTION

The distance inward from the edge of the covered surface over which the soil moisture content is affected by changes in climate has long been questioned. Despite the significance of this edge moisture variation distance, very few measurements of it have been reported. Consequently, two research sites were established in the U.S. in 1985 to study, among other objectives, the influence of climate on the edge moisture variation distance. An arid climate test site was constructed in Amarillo, Texas, and a wetter climate test site was constructed in College Station, Texas. Measurements have been taken over a period of several seasonal changes and trends are now apparent that provide new insight into how the soil around the perimeter of surface-supported structures is affected by the climate.

PREVIOUS MEASUREMENTS

"Edge moisture variation distance," "edge penetration distance," "edge effect," and other terms have been used to describe the distance beneath a surface cover measured inward from the edge over which the soil moisture content varies enough to cause soil movement or volume change and affect the performance of the surface-supported structure. Very few measurements of this value are available in the technical literature. Table 1 summarizes all of the published measurements known to this writer.

PREDICTING EDGE MOISTURE VARIATION DISTANCE

Because of the shortcomings of the B.R.A.B. (1968) and Parcher and Means (1968) relationships (Wray, 1978; Holland and Lawrance, 1980; Wray, 1980), this writer proposed a relationship between edge moisture variation distance and climate as represented by the Thornthwaite Moisture Index (TMI) (Wray, 1978). This relationship is depicted by the lower boundary of each cross-hatched curve of Figure 1 and was developed from analysis of existing slab-on-ground foundations. The cross-hatching was added when the PTI Design Procedure (PTI, 1980) was published to allow a designer to account for less than "perfect" drainage conditions, effects of vegetation, etc., by moving upward into the cross-hatching and increasing the "effective" edge moisture variation distance. However, this relationship was not based on direct measurements of climate and edge moisture variation distance. Thus, field studies to measure the effect of climate on the edge moisture variation distance were undertaken.

STUDY SITE

The test site was constructed with instrumentation to record changes in soil moisture conditions vertically as well as laterally, both outside and beneath a surface cover. Only the Amarillo site findings will be discussed here. College Station data and results are presented in detail elsewhere (Wray, 1989).

Description of Research Site

The surface cover representing a slab-on-grade foundation consisted of a 7.3 m wide x 12.2 m long rectangular flexible plastic membrane, chosen so that no significant resistance to soil swelling or shrinking would be present.

Table 1. Edge Moisture Variation Distance Measurements Reported in the Technical Literature.

Reporter	Measurement	Location	Reference
Ward	3 ft (0.9 m)	U.S.	Ward, 1953
Aitchison	3 ft (0.9 m)	Australia	Aitchison, 1965
de Bruijn	6 ft (1.8 m)	S. Africa	de Bruijn, 1965
Russam & Dagg	0.6 - 1 m	Kenya	Russam & Dagg, 1965
Holland	About 1.5 m	Australia	Wray, 1978
Washusen	1 m	Australia	Washusen, 1977
Holland & Lawrence	2.7 m	Australia	Holland and Lawrence, 1980

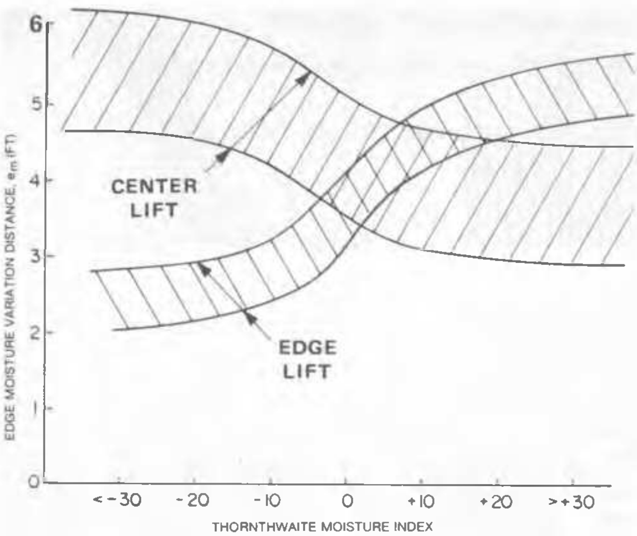

Figure 1. Approximate relationship between edge moisture variation distance and climate predicted from structural back-calculations (Wray, 1978; PTI, 1980).

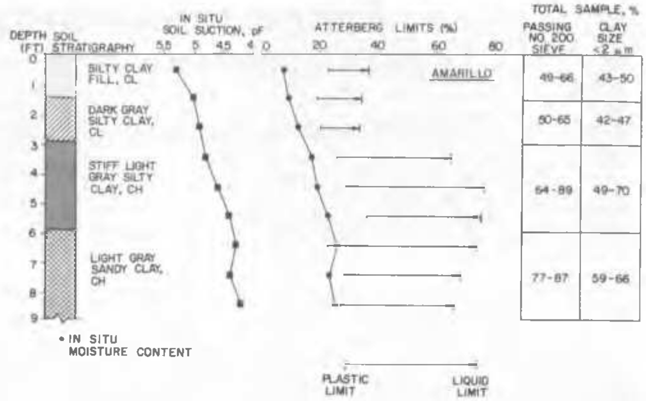

Figure 2. Soil Properties at the Amarillo site.

One row of subsurface instrumentation was installed 0.6 m on either side of the longitudinal canterline of the membrane. Each parallel row consisted of 17 "stacks" of instrumentation: 0.9 m outside the covered area, at the edge of the membrane, 5 sets at 0.6 m intervals inward from the edge of the slab, 4.6 m inward, and at the center of the covered area, 6.1 m from either end. The instrumentation was symmetrical about both the longitudinal and transverse centerlines. Each of the stacks had thermocouple psychrometers at depths of 0.3, 0.9, 1.5, 2.1, and 2.7 m. Elevation points were installed at 0.9 m intervals in both directions over the surface of the membrane as well as for a distance of 1.8 m outside the surface cover. All measurements were taken monthly. Other site construction and instrumentation details are presented elsewhere (Wray, 1989).

Subsurface Conditions

Four separate soil strata were identified at the site. Soil properties at the time of site construction are reported in Figure 2. The initial soil suction values were determined using the filter paper method (Wray, 1987). X-ray diffraction analysis indicated that the predominant clay mineral for each stratum was smectite, with percentages ranging from 32 to 45 percent of the clay content.

Climatic Data

Using government weather data for the 44-year period 1941-84 the mean TMI for Amarillo was found to be -560 mm/yr. The annual TMIs ranged from the wettest value of +60 mm/yr to the driest of -1060 mm/yr. The TMIs calculated for 1980-84, the 5 year period prior to the site installation, were -900, -550, -620, -790, and -600 mm/yr, respectively.

MEASUREMENTS

The measurements and observations reported below were taken from and made only with respect to the west half of the slab, the end constructed without a 0.45 m deep grade beam.

Climatic Measurements

The site received considerable rainfall immediately following its construction (Wray, 1987) and a greater than normal amount of precipitation continued throughout the measurement period (Wray, 1989). The TMIs for 1985-87 were -440, -160, and -260 mm/yr, respectively. Thus, the climate has been significantly wetter over the 3 years since the construction of the test site.

Surface Elevation Measurements

Over the first 12 months the site responded to the changes in climate by heaving and shrinking around the perimeter of the covered surface by as much as +0.10 and -0.03 ft, respectively (+30 and -9 mm) but showing relatively little change in the interior of the cover. However, a small mound in the center of the slab has gradually become more defined over the later measurements, recording a maximum heave, to date, of 0.09 ft (27 mm) (Wray, 1989). Plotting month-by-month changes in elevation, Figures 3a-d, show the surface elevation changes for elevation points 1.8 m outside the cover, at the cover's edge, and 0.9 m and 1.8 m inside the cover, respectively. As seen, the uncovered surface changes elevation radically from one month to the next. The point at the cover's edge experiences frequent elevation changes similar in nature to those of the uncovered point but not nearly as great. The points further to the interior experience very few changes in elevation, reflecting the effect of the surface cover on changes in soil moisture conditions.

Soil Suction Measurements

Soil suction was measured using calibrated thermocouple psychrometers. Figure 4 represents the soil suction conditions at the site at the end of the first month. Soil suction contours are plotted in units of pF [the common logarithm of the height of a water column

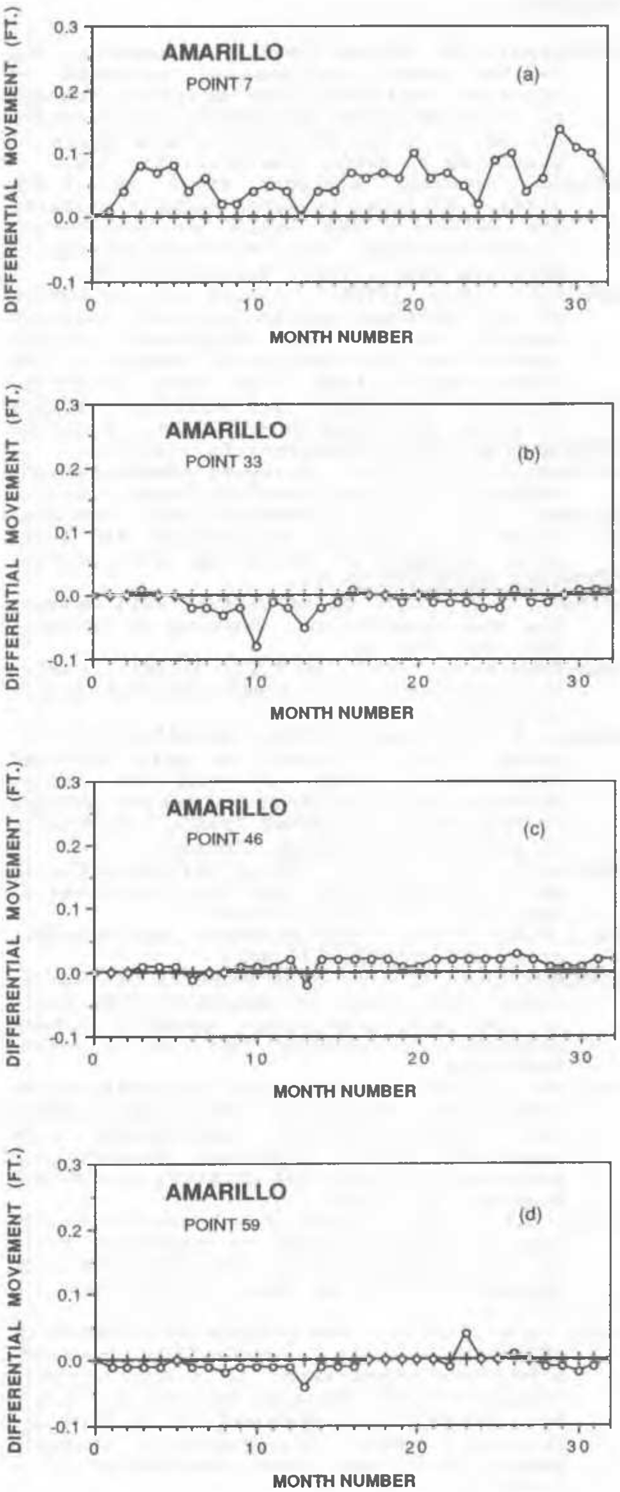

Figure 3a-d. Month-by-month changes in surface elevation at a point located: (a) 1.8 m outside the surface cover, (b) at the edge of the cover, (c) 0.9 m inside the edge of the cover, and (d) 1.8 m inside the edge of the cover.

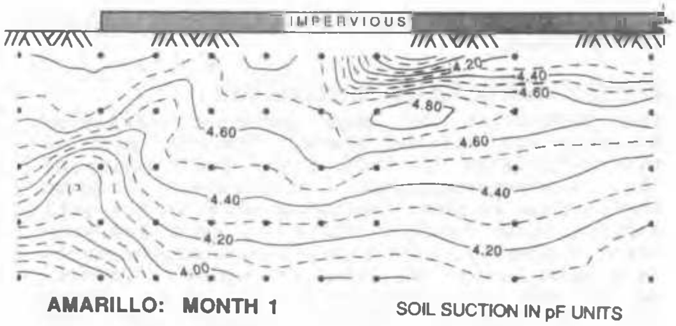

Figure 4. Contours of constant suction measured beneath the test site one month following cover installation.

measured in cm needed to give an equivalent suction pressure (Schofield, 1935)] with the contour intervals being 0.1 pF. Figure 4 shows the horizontal soil suction gradient in the soil to still be relatively well organized one month after installation of the cover with drier soil near the surface and progressively wetter conditions, in general, with depth. However, the soil immediately beneath the cover had become slightly wetter than the soil just below it, possibly because of the suction gradient existing at the time of cover installation and the essentially horizontal contour lines have been disturbed outside the cover, likely by the moisture that entered the soil as a result of considerable rainfall which occured immediately after the site construction.

The following months showed first a continuation of both observations noted in Figure 4, i.e., the soil beneath the slab interior becoming wetter and the moisture intrusion at the edge of the slab pushing deeper and further beneath the edge of the slab. However, as the months passed, the moisture conditions beneath the cover interior began to get drier but showed occasional point readings of significant wetness which usually disappeared in a month's time. The soil outside the cover and beneath the outer 1.8 m, in general, showed considerable change from one month to the next.

This sort of soil suction contour analysis was made by comparing the changes in soil suction from month to month. In making an overall evaluation of the month-by-month changes in surface elevations and soil suction conditions beneath the site, more than 30 months of measurements were reviewed. Some general trends or observations became apparent. In General: (1) the changes in soil suction beneath the interior of the covered surface are less than those occurring closer to the edge of the cover or outside the covered surface; (2) the changes in soil suction near the edge and outside the cover tend to occur more rapidly and with greater "volatility" than those changes beneath the interior of the covered surface; (3) monthly changes occured beneath the interior of the covered surface which, in some instances, were of localized significance; (4) cyclical changes in soil suction can be observed outside, at the edge, and well inside the interior of the cover; and (5) the magnitude of change in soil suction over the climatic cycle was significantly greater outside than that observed beneath the interior of the cover.

Discussion of General Observations

The definition of edge moisture variation distance was defined above. The key part of that definition is "affect the performance of the surface-supported structure." Space limitations prevent including more of the soil suction data contour plots in this presentation. However, more than 30 such measurements were made over the past 3 years. Careful review and evaluation of these plots showed that, in general, greater changes and more rapid changes in soil suction were observed outside a 4 to 6 ft (1.2 to 1.8 m) distance measured inward from the edge of the cover (or conversely, lesser changes occured inside this distance). This important observation suggests that the edge moisture variation distance for edge lift heave conditions at this particular site is between 4 and 6 ft. However, review of the elevation measurements made at the surface above the soil where suctions were found to be constantly changing does not reflect any appreciable surface movement inside a distance of 3 ft from the edge of the cover. In fact, the elevation measurements made at the edge of the cover [actually approximately 4 in. (0.11 m) inside the edge], Fig. 3b, show a considerable "damping" of the elevation changes when compared to the uncovered surface elevation changes, Fig. 3a.

CONCLUSION

A number of observations of changes in soil moisture conditions outside and beneath a surface cover have been made from more than 30 months of measurements. Surface measurements of soil heave and shrink have also been made. These measurements have been related to the climate at the test site. From careful consideration of these measurements, it appears that for edge lift heave conditions, the edge moisture variation distance at this site is less than 3 ft (0.9 m). Although this finding is somewhat inconclusive since the measurements were made laterally only to the nearest 2 or 3 ft (0.6 or 0.9 m), it nonetheless supports the predicted edge moisture variation distance of slightly more than 2 ft (0.6 m) which was deduced from structural performance criteria. Thus, it appears that for edge lift heave conditions in an arid climate, the edge lift curve of Figure 1 is valid. From all indications, several more years will be required before the long term centerlift heave condition develops under the cover to the point where center lift edge moisture variation distances can be measured and evaluated.

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