An Investigation of Granulated Calcined Clay in Landscaping

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FINAL REPORT
AN INVESTIGATION OF GRANULATED CALCINED CLAY IN LANDSCAPING
PROJECT IHD-1

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16. Abstract

The purpose of this investigation was the evaluation of calcined clay as a modifier of topsoil for backfill for landscaping plants. The calcined clay modified topsoil was compared with Illinois Standard Specification backfill using peat moss.

The results of laboratory tests indicate that peat moss is more effective in altering the void ratio, capillary porosity, liquid limit, and moisture storage capacity than is calcined clay.

The results of field trials established in Interstate highway landscaping projects indicate that soil modification obtained with calcined clay is essentially permanent and calcined clay modified backfill is more stable structurally than peat moss modified backfill. No significant differences in growth or mortality rates were found between calcined clay sections and peat moss sections. The cost of calcined clay treatments was approximately double the cost of peat moss treatments.

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SUMMARY

This final report relates the laboratory testing procedures and results as well as the field testing arrangements for comparing granulated calcined clay with peat moss as a modifier of topsoil for backfilling landscape plantings. The preparation of the backfill mixes and the selection of planting sites are discussed.

Peat moss was more effective than calcined clay in altering the void ratio, capillary porosity, liquid limit, and moisture storage capacity. Also, peat moss is considerably less expensive than calcined clay. The primary advantage of the calcined clay mix appears to be its stability, which may allow the elmination of brace wires for balled and burlapped plantings. Its better workability at high moisture conditions appears to be an advantage also.

No significant differences in growth or mortality rates were observed between calcined clay sections and peat moss sections.

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INTRODUCTION

The expanded program of landscaping of highways, especially on expressways, has intensified the need for backfill mixes of improved workability, permeability, and lasting qualities for economy in the planting and establishment of shrubs and trees. Peat moss has been quite satisfactory as an improver of most topsoils but has some limitations such as its rapid disappearance and a tendency to be muddy with clays during early spring and following heavy rains.

Calcined clay appeared, from literature on its use on golf courses and in green houses, to hold promise for improved workability at high moisture conditions and to have extended life. The cost of calcined clay is approximately double the cost of an equivalent amount of peat moss. The Illinois Division of Highways, on the recommendation of the Illinois Highway Development Council, proposed to field test a granulated calcined clay as a soil conditioner.

Two locations along interstate routes representing (1) rural downstate Illinois on FAI 57, Sections (25-8,87-1)LS and (87-1-1,18-1)LS, north of Effingham and (2) urban expressways of Northern Illinois along FAI 55, Sections 0104,659LS and 0407-656LS southwest from Chicago, were selected. Special provisions were approved by the U. S. Department of Transportation, Federal Highway Administration, for the inclusion of calcined clay on one-half of each area for comparison with standard specification backfill prepared using peat moss.

Laboratory testing was used to evaluate the field conditions and the interactions of the modifiers with the soils.

LABORATORY INVESTIGATION

Pilot Study

Prior to taking undisturbed cores of backfill and surrounding fill area, the laboratory procedures for testing these cores were used and developed to a smooth routine with personnel especially trained for the job. The topsoils used for these pilot tests were taken from the topsoil borrow site for the FAI 55 (Southwest Expressway) project in a field on the east side of Route Illinois 53 about one-quarter mile north of the intersection with US 66 (FAI 55). The legal description of this site is the southwest 10 acres (4.05 Hectares) of the northwest 40 (16.2) of Section 14, T37N, R10E, in northern Will County. The Will County soil map indicates that the soil is Saybrook silt loam, a medium textured, moderately well drained, prairie soil with a dark colored silt loam "A" horizon or Brunizem topsoil. Preliminary tests for physical properties indicated 5.8 percent total carbon by the wet combustion method, the specific gravity was 2.57, and the liquid limit was 37.4 percent.

Aggregate analysis by dry sieving showed the following aggregate size distribution.

Sieve No.	Percent Retained
3	.004
10	22.5
16	12.8
30	20.7
Passing No. 30	44.0

Although the soil has a large proportion of fine aggregate less than 0.59 mm. in size, its high organic matter content and general tilth suggest it to be an excellent backfill soil with little need for additional conditioning.

Results of the pilot test are shown in Table 1. Except for specific gravity and liquid limit tests, each value in the table is an average of five replicate tests. A study of the table shows the following:

(1) Peat moss was more effective in altering the void ratio, capillary porosity, liquid limit, and storage moisture storage capacity than was the calcined clay.

(2) Dry soils treated with peat moss tend to expand during soaking, and bulk dry density decreased to 1.1 or less on all samples so treated.

TABLE 1.

Physical Properties of Cylinders Molded From a Dark Colored, Medium Textured, Brunizem Topsoil Treated With Peat Moss, Calcined Clay, or Mixtures of Peat Moss and Calcined Clay at Three Treatment Levels

Treatment	Treatment Level (1)	Comp. Dry Density	Bulk Dry Density After Soaking	Specific Gravity	Liquid Limit	Moisture Content (%) (2)			Pore Space (%) (3)		
						60 cm Tension	Wilting Point	Available	Total	Capillary	Void Ratio
Soil Only		1.15	1.13	2.57	37.4	34.5	11.5	23.0	57.2	69.8	1.275
Peat Moss	Half Standard	1.15	1.08	2.47	50.4	43.6	16.1	27.5	60.6	81.6	1.314
Peat Moss	Standard	1.18	1.06	2.42	53.7	46.4	17.3	29.1	63.1	87.4	1.294
Peat Moss	Twice Standard	1.10	0.98	2.30	-	55.6	-	-	64.1	94.1	1.345
Calcined Clay	Half (4) Standard	1.14	1.14	2.59	39.2	35.5	12.1	23.4	55.9	72.3	1.267
Calcined Clay	Standard	1.17	1.16	2.58	40.9	37.2	12.7	24.5	55.5	78.1	1.229
Calcined Clay	Twice Standard	1.15	1.13	2.54	43.8	37.8	13.8	24.0	56.4	77.0	1.246
1:1 Moss-Clay Mixture	Half Standard	1.15	1.10	2.53	42.2	39.6	13.2	26.4	59.0	76.9	1.302
1:1 Moss-Clay Mixture	Standard	1.14	1.07	2.52	45.3	45.0	14.3	30.7	60.6	86.7	1.344
1:1 Moss-Clay Mixture	Twice Standard	1.18	1.09	2.45	64.2	43.6	21.1	22.5	60.0	84.3	1.286
1:3 Moss-Clay Mixture	Standard	1.15	1.10	2.53	46.9	40.8	14.9	25.9	58.7	80.5	1.288
3:1 Moss-Clay Mixture	Standard	1.18	1.11	2.52	56.4	43.8	18.3	25.5	59.6	78.0	1.294

(1) The treatment levels are based on 9 ft.^{3} [5] of calcined clay or 3.5 ft.^{3} [5] of peat moss per cubic yard [6] of topsoil as standard.

(2) The 60 cm. tension moisture level may be assumed to be near field capacity for purpose of comparison.

(3) Total porosity is that percent of the total volume that is pore space. Capillary porosity is the percentage of the total pore space that is capillary porosity.

(4) Treatment with half the standard amount of calcined clay produced little or no expansion. Therefore, the compacted dry density was used to calculate volume relationships.

(5) 1 cu. ft. = .0283 cm meter

(6) 1 cu. yd. = .765 cm meter

(3) Calcined clay treated samples expanded no more than the untreated control test.

(4) Calcined clay altered the capillary porosity but was less effective than the peat moss.

(5) Large amounts of peat moss added to the soil increased bulkiness of the sample, lowered the specific gravity, and increased the pressure required for compaction. Calcined clay altered the specific gravity only slightly and presented no difficulty in compacting to a bulk density of 1.15.

(6) Peat moss and calcined clay affect soils differently in mixtures and peat moss has the greatest effect for a given weight of material. The significance of these effects was lost in this instance since the untreated soil had relatively good physical properties in terms of plant growth requirements. However, many soils likely to be used as backfill soils in highway landscaping are not likely to be as good quality as the soil used in this pilot test.

(7) Variations in soil physical properties influencing the soil water-soil-air relationship can be measured by the method employed. The measure most likely to be important in soil-plant relations is the ratio of capillary to noncapillary pore space.

The above measures can have little significance unless they are considered in terms of plant requirements for oxygen and water. Obviously, there is some optimum condition which most nearly meets the needs of the plants growing in the soil. This condition can vary within limits and can satisfy the requirements of a wide variety of plants. Any material which can alter soil physical characteristics to bring them within the optimum range for plants can function as a soil conditioner. Results in Table 1 show that both calcined clay and peat moss can qualify in this respect.

<u>Introduction to Laboratory Analysis</u>

Any material added to the soil to modify its physical properties and improve soil-air-water-plant root relationships is a soil conditioner. Soil conditioners may be solid, liquid, organic, or inorganic. Peat moss, calcined clay, milorganite and krillium are good examples. They need not contain plant nutrients. Materials which add nutrients are subject to control under the Illinois Fertilizer act which regulates the sale of fertilizers in Illinois. Materials containing subminimal amounts of plant foot may be sold only as soil conditioners. Soil conditioners should be plentiful, inexpensive, uniform in quality, and capable of being added to the soil in large amounts without deleteriously affecting the soil chemistry.

The physical or chemical characteristics of soils, known to determine their quality as plant root media, which can be altered by addition of soil conditioners include (1) total pore space, (2) pore size, (3) ratio of coarse to fine pores, (4) available water storage capacity, (5) base exchange capacity, (6) compaction or dry density, (7) water intake rate, and (8) erodability. Measurable soil parameters that are related to the above soil characteristics include (1) particle size distribution (2) liquid limit, (3) plastic limit, (4) total carbon, (5) base exchange capacity, (6) porosity, (7) void ratio, (8) pore size distribution, (9) bulk dry density, and (10) permeability. Soils vary widely in physical properties and hence in their need for treatment. Soil conditioners also vary in the effects they produce when applied to the soil. Parameters most useful for comparing soil conditioners in terms of effectiveness as soil ammendments are most likely to be porosity, void ratio, pore size distribution, permeability, and available water holding capacity. Standardized procedures for measuring these parameters are needed.

There is increased interest in highway roadside beautification. Undesirable soil materials along the right-of-way may often be made quite suitable for backfill or top dressing for landscaping purposes by treatment with soil conditioners and plant nutrients. Some soil materials can be used without treatment, but treatment needs of some other soils are often too extensive and costly to be economical. Maintenance personnel and landscape architects should have available adequate knowledge of all types of soil ammendments and of soil needs to select the most economical and adequate treatments for the soil materials encountered in highway construction and maintenance in all parts of the State. The study described here was intended to obtain data useful for comparing peat moss and calcined clay as soil conditioners. Once standardized, the procedures used in this study should be able to characterize any type of material intended for similar uses. Studies such as this one could provide data useful for

(1) modifying existing specifications or preparing specifications for other new materials intended for use as soil conditioners,

(2) establishing bases and criteria for evaluating the qualities of soil conditioners and estimating quantities to use,

(3) obtaining further knowledge of the requirements of soil material in various parts of the State of Illinois for soil conditioning, and

(4) gaining new knowledge of the requirements of various types of plant materials relative to the ability of soils to transmit air and water and to provide plant nutrients.

Principles and Definitions

Soil physical condition is important to growing plants. It is that quality of soils which is related to desirability as a plant root medium. Soils in good physical condition should be able to (1) absorb and retain an adequate supply of moisture, (2) transmit excess water rapidly enough to avoid damage to water sensitive plants, (3) allow for adequate diffusion of oxygen into the soil for respiration and carbon dioxide out of the soil, and (4) offer an acceptable low physical resistance to plant root growth. A unit volume of uncompacted topsoil is composed of a mixture of organic and inorganic solids, airspace (voids), and water. A unit volume of oven dry (230° F) (110°C) soil contains only solids and void space for all practical purposes. The weight of a unit volume of oven dry soil relative to water is termed "dry density" or "bulk dry density." Dry density of topsoils may vary from 1.8 or 1.9 downward depending on compaction, fabric (particle arrangement), specific gravity, particle size distribution, and pore volume.

The unit weight of the solid portion of a mass of soil relative to water is its "specific gravity." Specific gravity of topsoil may be as high as 2.78-2.79 or higher and as low as 2.0 or less depending on the mineral constituents and the admixture vegetal residues. The specific gravity of any special soil sample is thus the weighted average of the specific gravities of all solid constituents of the unit volume. Additions of peat moss to soils has a significant effect on the specific gravity of the treated oils, but calcined clay has negligible effect. Peat moss has a specific gravity equal to or less than 1.0 while calcined clay is similar to the soil minerals in density of its solids.

The magnitude of difference between bulk dry density and specific gravity is related to pore space and has been used as a measure of the total pore space. "Porosity" can be expressed as the percentage of a unit volume that is pore space and can be determined from the equation

$$P = 100 \frac{(d - d_1)}{d}$$

where P equals the percentage of the total volume that is pore space, d is specific gravity, and d_1 is dry density. The ratio of voids to solids (voids/solids) varies directly as porosity.

Soils in a normally good physical condition should contain at least 50 percent pore space. Such soils would have bulk dry densities ranging from about 1.35 downward and a void-solids ratio of 1.0. Soils in good condition can have a void ratio of 3.0 or higher. Soils with low porosities (less than 50 percent) are less desirable for plant growth and may have bulk dry densities greater than 1.30-1.35 and void ratios less than 1.0.

Porosity is also dependent to some extent on particle size distribution (see Figure 1). Coarse textured soils can have low porosities and high bulk dry densities (greater than 1.3 or 1.4) while still being considered in relatively good physical condition. Clay soils with large quantities of fine particles (clay size) may have low bulk dry densities (less than 1.3) and still be considered "tight" or in relatively poor physical condition. Although the porosity is high, the soil pores are extremely fine (small radii) and hence limit the transmission of air, water, and plant roots. Therefore, to be in good physical condition a soil should contain sufficient quantities of relatively coarse pores which transmit air and water quickly. Good quality soils favorably combine the water holding capacity of capillary pores

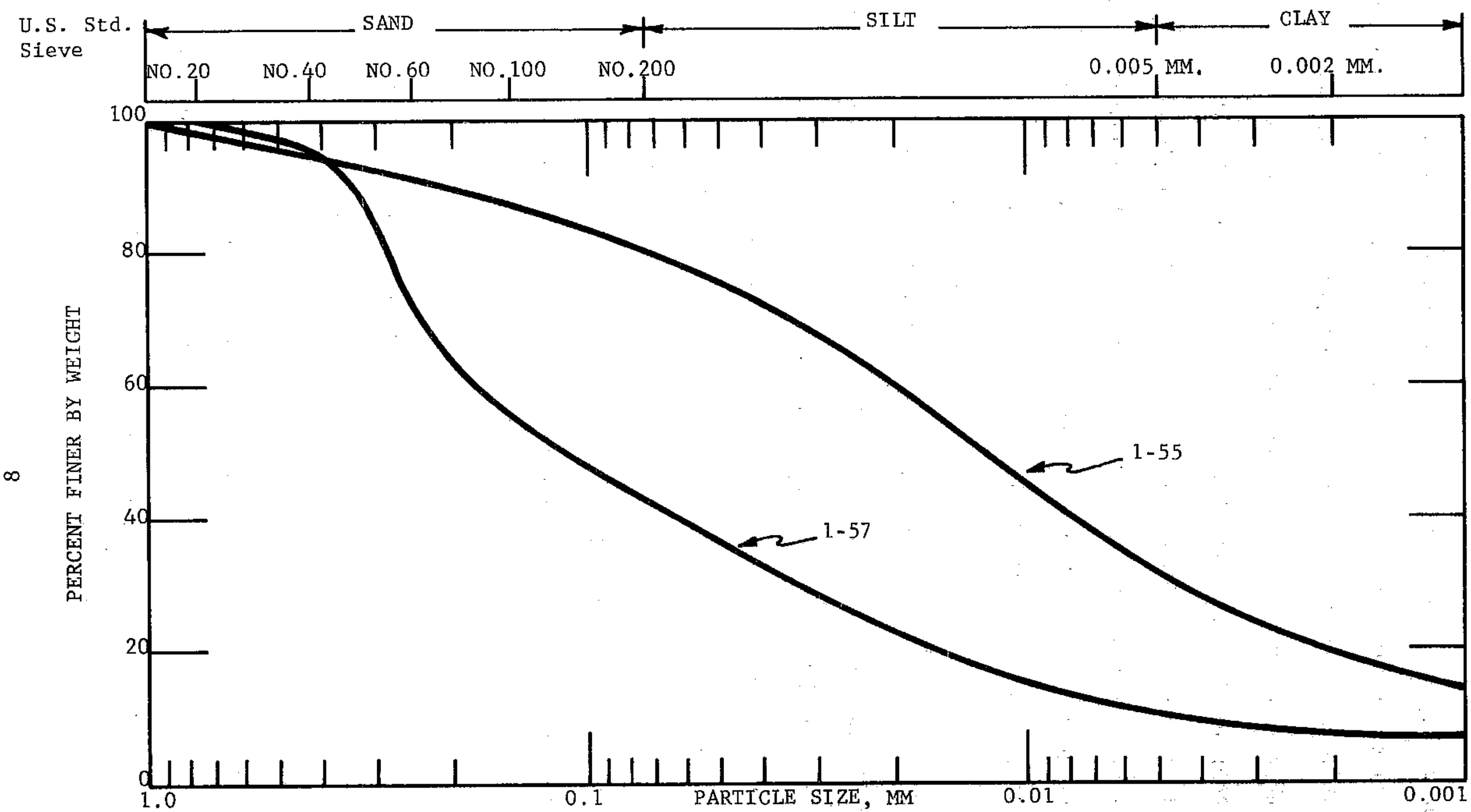


Figure 1. Particle size distribution of original topsoils

with good permeability provided by an adequate proportion of coarse or macro-pores.

Soil conditioners can be rated in terms of their effects on the solids-porosity characteristics, pore size distribution, and water holding capacity of soils. The soil micro-pores determine the soils moisture-holding capacity. "Micro-porosity" of a soil can be measured by saturating it with water and subjecting it to a tension force of known value. "Moisture tension" is the tension applied to the moisture in a soil sample through a tension table or other device. It is equivalent to the length of the water column suspended below the table and is measured in centimeters from the surface of the tension table to the lower tip of the overflow tube of the tension control device. A photograph of the tension table used in this study, which was designed and built in the laboratory, appears in Figure 2 and a diagram of it appears in Figure 3. Moisture tension can be measured in terms of the length of the water column suspended below the table in atmospheres, centimeters, inches, or "pF." The "pF" is the logarithm of the length of water column in centimeters, needed to produce a given moisture tension. Centimeters are used in this study.

Field capacity refers to the quantity of water, measured on an oven dry basis, which is retained by the soil after all coarse soil pores have been allowed to drain. It represents that quantity of water held by the soil in the capillary pores against the force of gravity and it is approximately equal to the moisture equivalent (measured by centrifuge). Various tension values have been suggested in the literature for field capacity, such as 1/3 of an atmosphere or a pF of about 2.537. Russel and Richards have suggested a pF or about 2.7. For this study a value of 60 cm was used, which is equivalent to 0.06 atmospheres or a pF of about 1.8. The tension table used in this study was limited to a low range in tension but was adequate for the purpose of the study. Small errors involved in field capacity measurements are negligible as water used by plants is held in the soil at tensions up to 15 atmospheres (pF = 4.2) or better than 10 times the tension force at field capacity. Field capacity is an

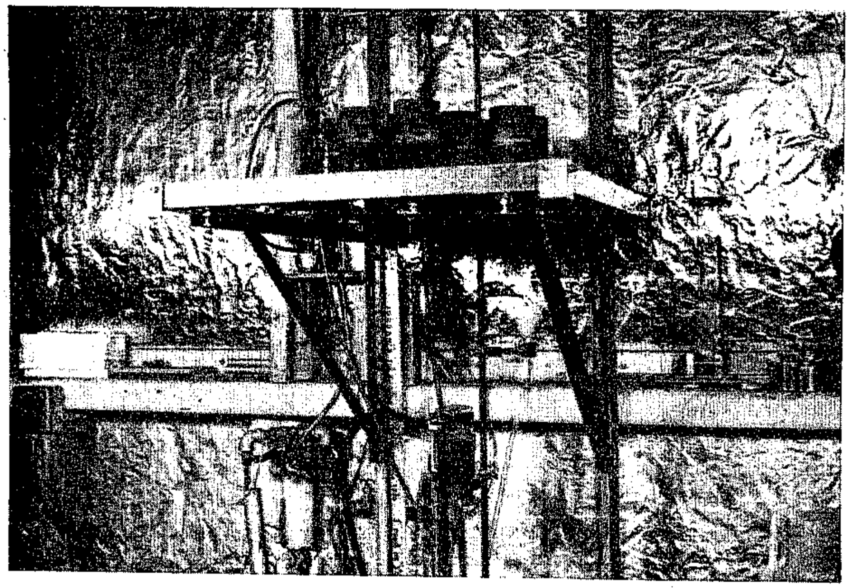
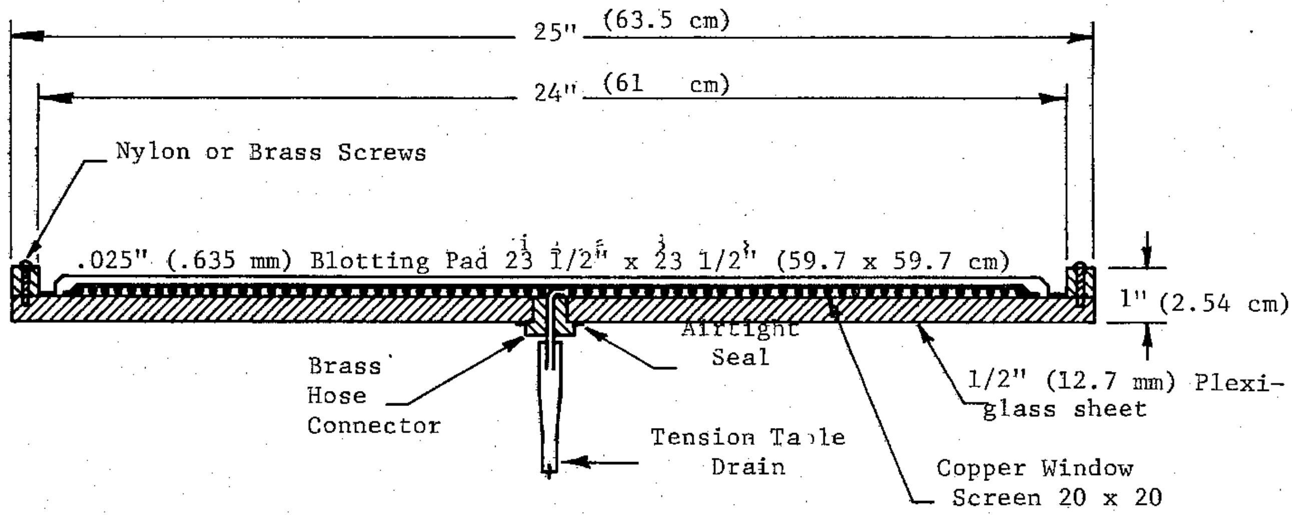
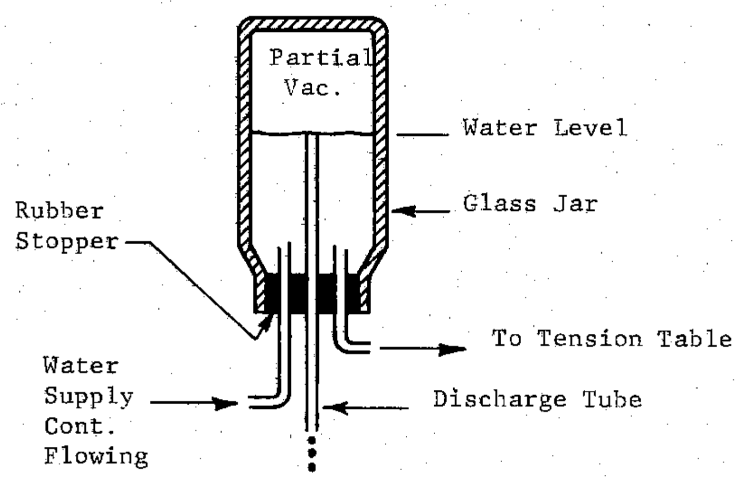


Figure 2. Tension table in operation.



TENSION TABLE
(Not to scale)



TENSION CONTROL
(Not to scale)

Figure 3. Tension table design

important measure of soils because it serves to differentiate between coarse and fine pores or capillary pores.

"Wilting point" is the soil moisture content on an oven dry basis at which plants can no longer remove enough water from the soil to remain turgid and are thus permanently damaged. Wilting point is equivalent to a tension of about 15 atmospheres or a pF of about 4.2. The wilting point for the soil samples from the plant sites was estimated from the liquid limit. Broadfoote and Burke found in 1958, from a study of 35 soils ranging widely in texture from coarse to fine, that they could determine the wilting point from the liquid limit using the equation

$$W.\ P. = -2.0 + 0.36\ \text{Liquid Limit}$$

The correlation coefficient was 0.86 at the 1 percent confidence level for the soils they studied.

Capillary pore or micro pore volume is the volume of pore space that will retain its water against a tension force of 60 cm of water. Macro porosity is the portion of the pore volume that drains under a tension of 60 cm of water.

Available water is the water held in the soil at tensions within the range usable by plants. It is the measured difference between the moisture percentage at field capacity and that at the wilting point.

Total pore volume (Vp) is the portion of the total volume of a compacted soil specimen that is occupied by pore space. Porosity is the percentage of the total soil volume that is pore space.

Specimen volume (Vt) is the total volume of the soaked soil specimen with pores water saturated. It is equal to the internal volume of the cylindrical mold plus whatever expansion occurs during the soaking process.

A soaked soil specimen (48 hours soaking) is saturated when it will no longer absorb water at zero tension. During the soaking process in this study the water level was held even with the top of the soil specimen. Higher saturation values could be obtained in a vacuum, but the method used here is thought to be more representative of the natural field condition. It is less than 100 percent saturation.

Solid volume (Vs) is the portion of the specimen volume occupied by solid soil particles. It is equal to:

$$Vs = Vt \frac{d_1}{d}$$ where d_1 = Bulk Dry Density
d^1 = Specific Gravity of the Solids

It is also equal to the difference between the specimen volume and the total pore volume.

Void ratio for the purpose of this study is defined as the ratio of the total pore volume (Vp) to the solids volume (Vs) or

$$\text{Void Ratio} = \frac{Vp}{Vs} = \frac{Vt - Vs}{Vs}$$

Experimental Procedures

In the laboratory both soil conditioners were tested on two soils representative of the two landscape projects. Test Cylinders were prepared from mixtures of each material using three treatment levels and both soils. Soil conditioner materials were tested individually and in mixtures with treatment levels bracketing the project specifications for treatment of backfill soils with soil conditioners. Each combination of variables was replicated five times, and tests of the untreated soils were included as the control.

In addition ten planting sites were selected at each landscape project under study for observation and for testing under natural conditions. Five of the sites were selected in the peat moss treated backfill soil area, and five were selected in the calcined clay treated backfill soil area. Each of the five test sites varied further in plant type, natural drainage, landscape position (bridge cones, roadside slopes, shoulder plantings, etc.), and salt exposure. Five test cores were obtained from the backfill soil inside the water saucer at each test site, and five additional cores collected outside the water saucer were in the natural embankment or roadside slope soils. All cores were tested in the same manner as the prepared test cylinders in the laboratory test.

Finally, a complete set of clean composite samples was collected from the backfill soil inside the water saucer at each plant site and from the embankment or natural roadside soil outside the water saucer at each test site. Phosphorus and potash tests were run on these samples. Soil reaction and total organic carbon were also determined. Five cylinder replicates from each test site were combined after testing and used to run liquid limits, particle size distribution, and specific gravity. Specific gravity and liquid limit tests were run on the prepared test cylinders.

All data are presented in the results and discussion section.

Methods

Mixtures of soil and soil conditioner were prepared by adding the quantities (grams) of air dry soil conditioner shown in Table 2 to 2270 grams of the two backfill soils and mixing in a rotary mixer for 15 minutes.

Five test cylinders of each mixture were prepared by compacting 465 grams of the mix into steel cylinders of approximately .0135 cu. ft. (382 cc) in three lifts (155 grams each). The cylinders were fitted at the base with a cover of two ply fine mesh bleached cheesecloth held in place by a rubber band and at the top end with a two-inch steel ring cut from old cylinders (same diameter) and firmly held in place with masking tape. The masking tape seal was waterproof. The bulk dry density of the compacted specimens was 1.2. During the soaking process the specimens expanded, and the final dry densities varied according to the amount of expansion that took place. The dry densities after treatment varied between 1.04 and 1.18.

The field cores from planting sites were obtained by forcing a steel cylinder into the soil with a hammer as directed in the AASHO interim method T204-64 I for measuring soil dry density in the field. The field cylinders were lifted from the

TABLE 2

OUTLINE OF TREATMENTS AND TREATMENT LEVELS[1]

Treatment	Peat Moss Low	Peat Moss Med.	Peat Moss High	Calcined Clay Low	Calcined Clay Med.	Calcined Clay High
Peat Moss	100	200	400	-	-	-
Calcined Clay	-	-	-	220	441	882
Peat + Clay 1:1[2]	50	100	200	110	220	441
Peat + Clay 1:3	-	50	-	-	331	-
Peat + Clay 3:1	-	150	-	-	110	-
Peat + Clay 1:2	-	67	-	-	295	-
Peat + Clay 2:1	-	135	-	-	145	-

(1) Weights are air dry soils and soil conditioners. For oven dry basis, see Table 5.

(2) A moderately high level was used for the third treatment of the mixtures with the backfill soil from Interstate 57 because the high level treatments were difficult to compact due to the large volume of peat moss present. Amounts of the 1:1 mixture were reduced to 150 grams of peat moss and 331 grams of calcined clay in the mix.

soil, trimmed to standard volume, and placed in marked watertight containers for transport to the laboratory. At the laboratory they were removed from the containers, retrimmed to exact volume, and the cheesecloth base cover and upper steel ring attached in preparation for treatment.

Both the laboratory test cylinders and the field cores were soaked in a water bath at zero water tension for 48 hours or until they were saturated. The steel rings attached to the cylinder tops permitted water level adjustment to the height of the test cores but forced water to enter the core from below. This procedure was intended to improve the uniformity of air displacement in the test cores and raise the final saturation percentage nearer to 100 percent.

Following saturation, the test cores were placed on a drain board for five minutes, weighed, and placed on the tension table for 24 hours or until equal moisture tension was established between the soil capillary pores and the table tension. (Fine textured soils normally require longer than 24 hours to reach equilibrium, but experience showed that 24 hours was adequate for the soils under test.)

Once equilibrium was reached, the test cores were removed from the tension table and reweighed, and the final moisture content was measured. The material from each test remaining after the moisture samples were removed was sampled for specific gravity, liquid limit, and particle size analysis.

The total amount of water contained in the saturated test cores was assumed to be equivalent to the total amount of macro-pore space. The water remaining in the soil at 60 cm tension was assumed to be equivalent to the total micro-pore space. Further assuming the specific gravity of water to be equal to 1.0 (error is negligible at laboratory temperatures), weights of water could be converted to volumes and the total pore space, macro-pore space, and micro-pore space computed on a volume basis. The volume of solids was obtained by difference.

These procedures provided data suitable for comparing the effects of the soil conditioners on the pore space characteristics of two soils under controlled conditions

The measurements on field test cores serve to characterize the physical conditions prevailing at each test planting site, and the chemical tests assess the plant nutrient status of the soils at each test planting site. The phosphorus tests, potash tests, and pH tests were carried out as directed by the Agronomy Department of the University of Illinois, and the tests were calibrated in accordance with procedures recommended by the University of Illinois. The results could be used to recommend fertilizer application rates if desired.

Results and Discussion of Laboratory Testing

The laboratory studies were designed to bracket the project specifications which called for 3.5 cubic feet (.099 cubic meters) of peat moss or 9 cubic feet (.255 cubic meters) of calcined clay per cubic yard (.765 cubic meters) of backfill soil. For convenience in the laboratory it was decided to add the soil conditioners on a weight basis. Bulk dry densities of 0.5 and 1.15 were used for the peat moss and calcined clay to convert volumes to weight. Table 3 shows the weight in grams (oven dry) of peat moss and calcined clay used for each of the treatment levels together with the relative proportions of each in percent on both weight and volume bases. The actual amounts required by the project specifications are also shown for comparison purposes. Table 3 shows that the peat moss treatment level 2 was about 1.1 percentage points higher than the project specification on a weight basis and about 3.5 percentage points higher than standard on a volume basis, and the calcined clay treatment level 3 was about equal to the project specification. An additional calcined clay treatment level would be desirable to complete the test series. Also, combinations of moss and calcined clay were tested using ratios of 1:1, 1:2, 1:3, 2:1, and 3:1 peat moss to calcined clay. The 1:1 mixtures were added at all treatment levels, but the 1:2, 1:3, 2:1 and 3:1 mixtures were tested only at the intermediate treatment level. The percent composition of the mixtures by weight and by volume is shown in Table 4 which serves to better orient the experiment in terms of the project specifications.

TABLE 3

WEIGHT-VOLUME RELATIONSHIPS FOR THE SOIL CONDITIONERS BY TREATMENT LEVEL

Treatment Level	Soil Grams	Amount of Soil Conditioner Added: Peat Moss (1) Grams	Peat Moss Weight (%)	Peat Moss Volume (%)	Calcined Clay (1) Grams	Calcined Clay Weight (%)	Calcined Clay Volume (%)
Project Specifications	2268	147.3	6.1	11.5	869	27.7	25.0
Level 1	2268	88	3.7	8.8	220	8.8	8.1
Level 2	2268	177	7.2	15.0	441	16.3	14.5
Level 3	2268	353	13.5	26.0	882	28.0	25.2

(1) Calculations based on a bulk dry density of 0.5 for peat moss, 1.15 for calcined clay, and 1.0 for the soil. Values based on laboratory measurements.

TABLE 4

COMPOSITION OF PEAT MOSS AND CALCINED CLAY MIXTURES
WITH SOIL AT ALL TREATMENT LEVELS

Treatment Level	Ratio Peat Clay			Mixture Composition					
				Peat Added		Clay Added		Mixture	
		Weight	Volume	Weight (%)	Volume (%)	Weight (%)	Volume (%)	Weight (%)	Volume (%)
1	1/1	.40	1.04	1.8	4.1	4.5	3.9	6.4	7.9
2	1/1	.40	1.04	3.4	7.5	8.6	7.2	12.0	14.7
3	1/1	.40	1.04	6.1	13.1	15.3	12.6	21.4	25.6
2	1/3	.133	.35	1.7	3.8	12.5	10.8	14.1	14.6
2	3/1	1.20	3.1	5.3	11.2	4.4	3.6	9.7	14.8
2	1/2	.20	.46	2.2	4.4	11.3	9.7	13.5	14.2
2	2/1	.82	1.9	4.7	9.0	5.7	4.8	10.3	13.8

Technical precision is enhanced by working with materials on a weight basis. Weights are directly additive, but volumes are not because final volumes of mixtures depend on particle size, arrangement, and packing degree. In compacting to standard volumes, packing is also influenced by the specific gravities of the constituents. Large specific gravity differences result in detectable differences in packing when the proportions of components in a mixture are varied. These factors account for the variable nature of the percentage shown in both tables. For closer duplication of treatment levels related to standard specifications, which are stated on a volume basis, mixtures should probably be prepared on a volume basis. For better comparisons of widely different soil conditioning materials, the weight basis is probably the most suitable as long as differences in specific gravity are considered.

The effect of specific gravity difference between peat moss and calcined clay on the final specific gravity of the mixtures is illustrated in Table 5. Study of the table shows that peat moss reduced the specific gravity of soil mixtures in which it was used as the soil conditioner by about 0.32 units at the high treatment level while calcined clay reduced it by only .03-.06 units. There was a general increase in volume per unit weight of loose soil-peat moss mixture with each treatment level but relatively little change in volume per unit weight for the calcined clay treatments. Examination of Figures 4 and 5 shows that adjusting the micro pore space and total pore space for variation in specific gravity reduced variability of the data and improved linearity indicating that the specific gravity variation did affect the results. The effect of variation in peat moss increments was to produce a corresponding change in the total pore space and pore size distribution. Higher compaction as a result of increased volume per unit weight would tend to reduce pore size. This result was partially overcome by the increased expansion of the peat moss treated soils over calcined clay treated soils during the soaking period. More study is desirable to further evaluate the material's effect with specific gravity variations controlled.

TABLE 5

AVERAGE EFFECT OF SPECIFIC GRAVITY OF SOIL CONDITIONERS ON FINAL SPECIFIC GRAVITY OF SOIL MIXTURES

	Treatment Level (1)		
Treatment	1	2	3
Peat Moss	2.48	2.39	2.27
3 Peat/1 Clay	-	2.45	-
1 Peat/1 Clay	2.54	2.51	2.44
1 Peat/3 Clay	-	2.51	-
Calcined Clay	2.53	2.57	2.56

(1) Average specific gravity of soil was 2.59, peat moss 1.0, and calcined clay 1.9-2.4.

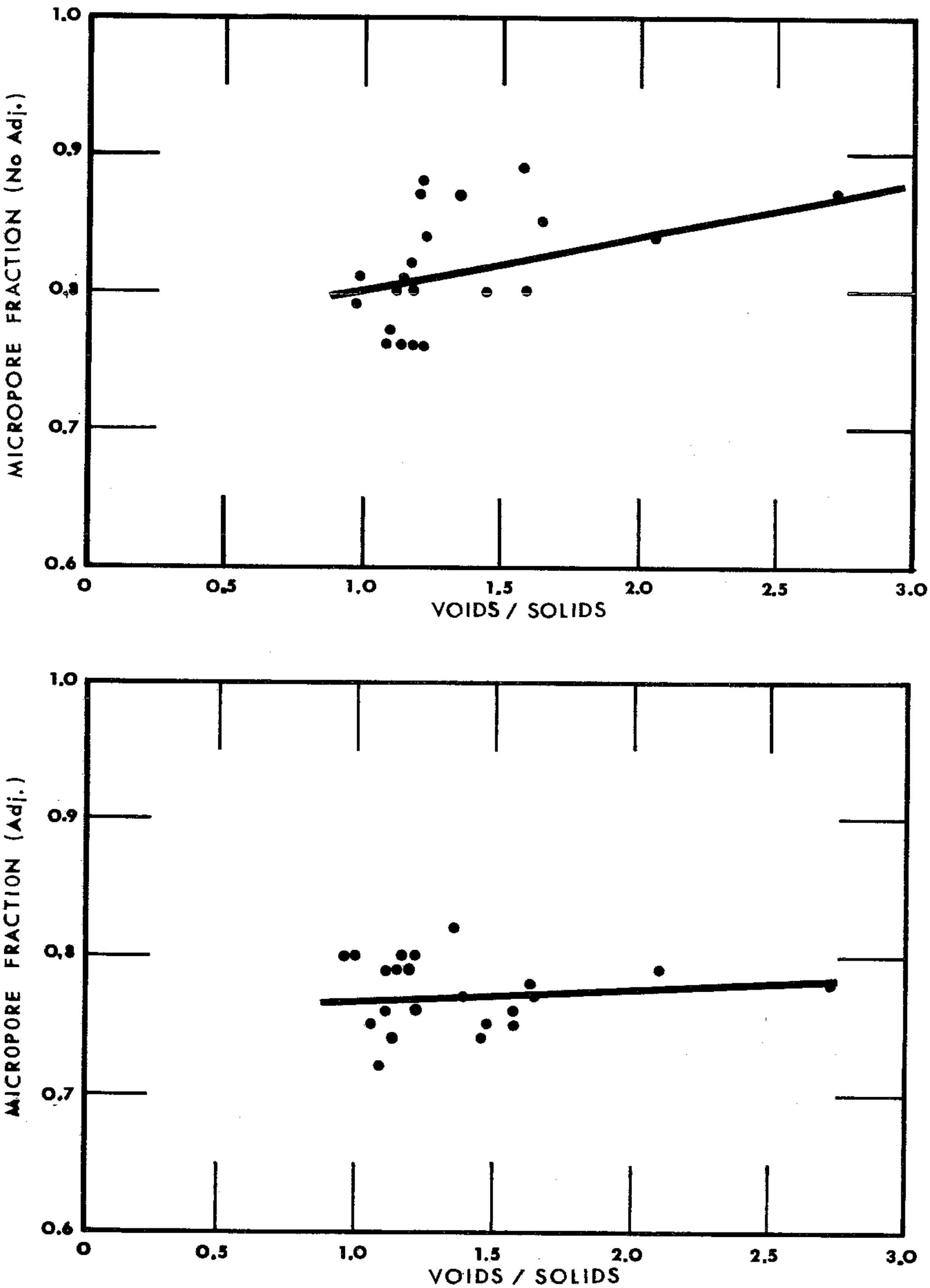
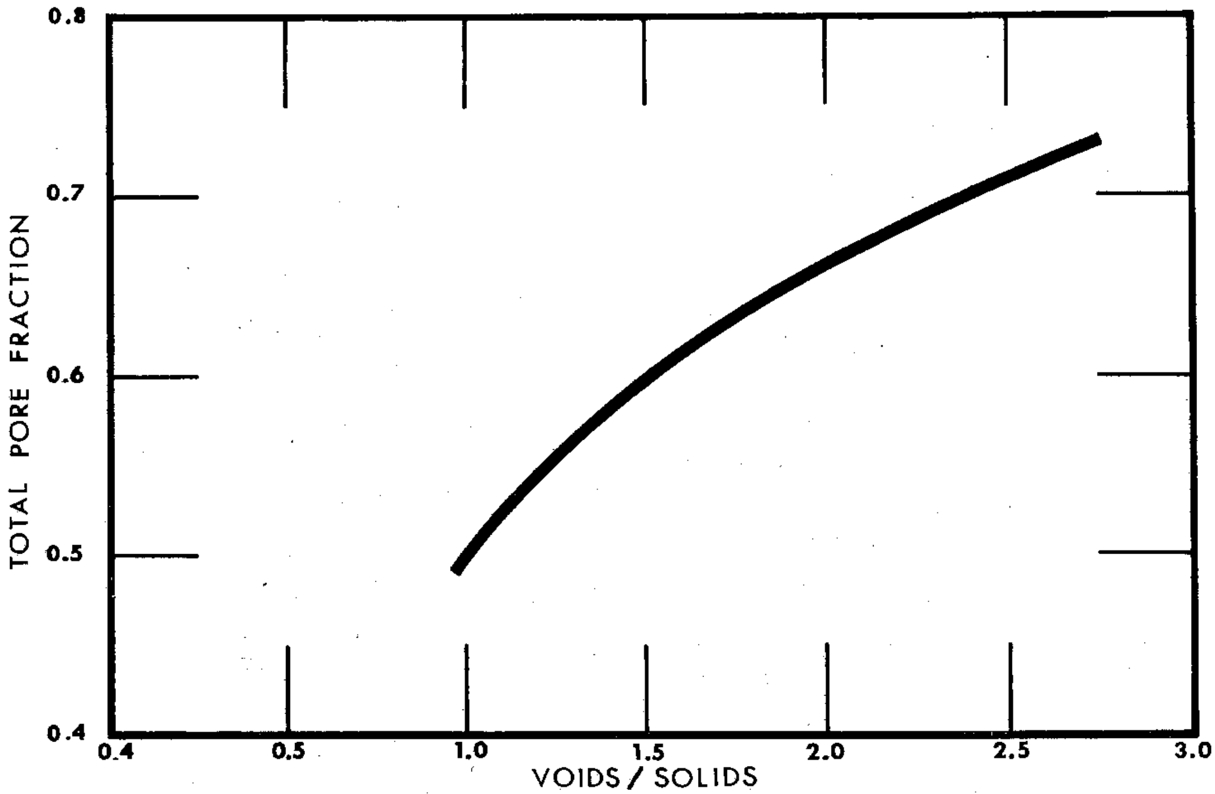


Figure 4. Voids vs. Solids Ratio for micropore fraction



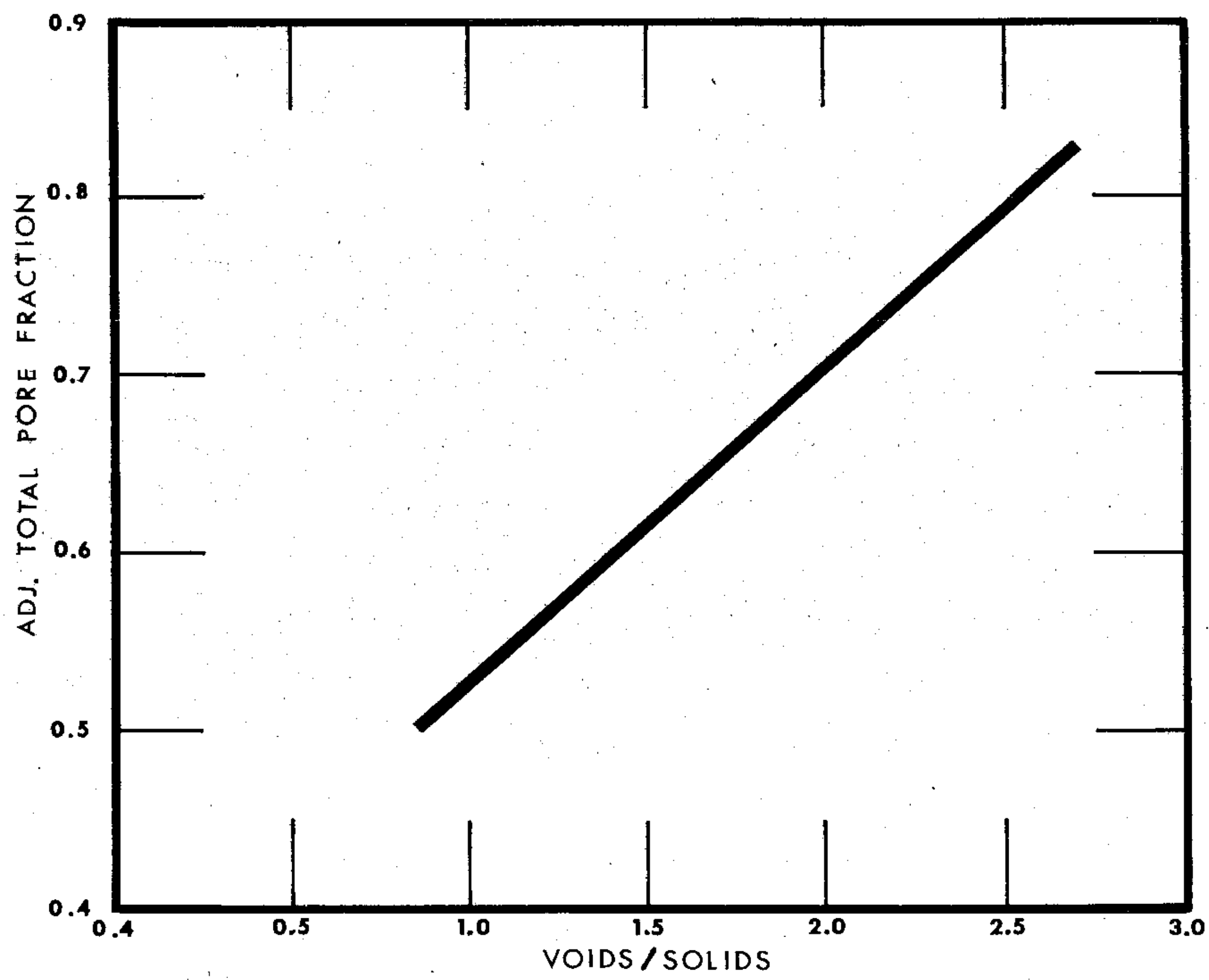


Figure 5. Voids vs. Solids Ratio for Total Pore Fraction

The effect of aggregation of soil particles was also considered. In preparation of the soils for treatment, they were air dried and passed through a No. 4 sieve. The aggregate size distribution of the prepared soils is indicated by the dry sieve analysis of the Stevenson Expressway soil tabulated in Table 6.

TABLE 6

DRY SIEVE ANALYSIS OF SOIL AGGREGATE DISTRIBUTION
FOR SOIL FROM I 55 LANDSCAPE PROJECT

U.S. Standard Sieve No.	Opening Size (inches)	Opening Size (mm)	Percent Finer by Weight
-	.371	(9.42)	100.00
-	.263	(6.68)	99.6
10	.0787	(2.00)	77.4
16	.0469	(1.19)	64.4
30	.0232	(.59)	43.8

Normally, the aggregate status of the soils is an important factor affecting porosity characteristics and permeability of soils, but under the conditions of this study, compaction of the samples to a bulk dry density of 1.2 crushed most of the large aggregates. Appearance of the extruded cores after testing indicated that most aggregates were crushed in the initial compaction process.

Expansion of the 2 3/4-inch (7-cm) diameter, 4-inch (10.2-cm) high test cylinders during the initial saturation treatment was a significant factor influencing the volume of pore space. Table 7 shows the measured expansion rate for both peat moss and calcined clay at each of the three treatment levels. The table shows that peat moss expanded greatly, while the calcined clay tended to reduce the tendency of the soil to expand. Most of the expansion in the control was accounted for by the Stevenson Expressway soil, which expanded about 0.51 cm. The I 57 soil alone expanded only about 0.2 cm. The effect of the expansion of peat moss treated soils is

TABLE 7

AVERAGE INCREASE IN HEIGHT (CM) OF MOLDED TEST CYLINDERS DURING INITIAL SOAKING

Treatment	Peat Moss	Calcined Clay
0	.34	.34
1	.75	0.10
2	1.0	0.11
3	1.61	0.22

interpreted to indicate that soils treated with peat moss have the ability to expand after compaction during planting operations. When they are moistened with water, they will expand, and the expanded volume results in a bulk dry density value of 0.9-1.10. Calcined clay treated soils do not appear to have this property. Expansion characteristics of calcined clay treated soils are largely those of the soils themselves. Peat moss treated soils are likely to be more desirable backfill soils, because they should be more tolerant of mishandling, particularly with respect to overcompaction, than calcined clay treated soils. On the other hand calcined clay treated soils may be less likely to heave plant roots or to have the ball rotate in the hole, thus probably reducing or eliminating brace wire requirements.

Test data on mixtures of the soil conditioners as a soil treatment were intended to further test the relative effects of the soil conditioners on the soils, to further test the void ratio as a measuring parameter, and to provide some basic data for evaluating qualities of mixtures as soil conditioning material. Table 8 shows the effect of mixtures of peat moss and calcined clay on the pore space of soils as measured by void ratio. Table 9 shows the changes in void ratio.

In comparison the project specifications called for about 2.4 times as much calcined clay as peat moss for the standard treatment on a volume basis. On the other hand calcined clay may be slightly more effective in increasing or maintaining the

TABLE 8

EFFECT OF SOIL CONDITIONER MIXTURES ON VOID RATIO
BY TREATMENTS AND TREATMENT LEVELS

Treatment Level	Moss (Pure)	3 Moss 1 Clay	2 Moss 1 Clay	1 Moss 1 Clay	1 Moss 2 Clay	1 Moss 3 Clay	Clay (Pure)
0	.882	-	-	-	-	-	.882
1	1.372	-	-	1.130	-	-	.480
2	1.871	1.464	1.175	1.192	1.396	1.632	1.161
3	2.148	-	-	1.273	-	-	1.122

(1) Mix proportions are only approximate values. More precise values can be obtained from Table 3.

TABLE 9

RELATIVE EFFECT OF SOIL CONDITIONERS

Treatment Level	Change in Void Ratio	
	Peat Moss	Calcined Clay
1	.127	.010
2	.136	.017
3	.134	.011

proportion of the total pore space of the soil that is macro or noncapillary pore space and hence the permeability. Table 10 indicates the average percentage of the total pore space that was noncapillary.

The table shows that peat moss has a greater effect on the void ratio than calcined clay and that the soil conditioners together have a beneficial effect on the soils, because they also tend to increase the ratio of voids to solids.

TABLE 10

EFFECT OF SOIL CONDITIONERS ON MACRO-POROSITY

Treatment Level	Average Percentage of Macro-pores			
	Peat Moss		Calcined Clay	
	a	b	a	b
0	.23	.23	.23	.23
1	.17	.21	.20	.20
2	.16	.22	.24	.24
3	.12	.23	.22	.23

(1) a - Measured macro-pore space

b - Measured macro-pore space adjusted for effects related to difference in specific gravity

The laboratory studies indicate that the void ratios of treated soils can be varied by treatment with soil conditioning materials and that the variation is generally proportional to the amount of additive used. Results also indicate that the void ratio could be a useful measure in studies of plant-soil relations. In cases where the physical nature of soils tends to be a limiting factor in plant growth, the void ratio should be usefull in understanding the extent of the limitation. In cases where soil aeration could be a limiting factor to plant growth, void ratio should be helpful for better understanding the possible causes and for selecting the best possible remedies. This type of approach to the study of plant-soil relations permits wide latitude in the types of soil amendments that can be studied and types of plant material that may be used and can be applied to most all mineral soils that may be selected for treatment and improvement as a medium for plant roots regardless of their nature.

Study of the data also shows that soils behave differently when treated with peat moss and calcined clay. The possibility that Illinois soils may differ in treatment needs suggests that additional economy could be realized by allowing

Table 10a

EFFECTS OF PEAT MOSS AND CALCINED CLAY AS SOIL CONDITIONERS ON PORE SIZE DISTRIBUTION OF TWO BACKFILL SOILS

Treatment Type	Treatment Level	Solids Portion		PORE SIZE DISTRIBUTION Total Pore Space		Micropores (1)		Voids/Solids		Available Water Supply GMS/CC	
		I-55	I-57	I-55	I-57	I-55	I-57	I-55	I-57	I-55	I-57
None	0	.50	.56	.50	.44	.77	.78	0.977	0.787	.25	.24
Peat Moss (2)	1	.42	.43	.58	.57	.80	.87	1.393	1.351	.26	.42
Calcined Clay	1	.51	.50	.49	.50	.79	.81	0.968	0.991	.25	.32
Peat Moss	2	.32	.38	.68	.62	.84	.85	2.101	1.641	.26	.39
Calcined Clay	2	.45	.48	.55	.52	.76	.77	1.215	1.107	.28	.31
Peat Moss	3	.17	.39	.73	.61	.87	.89	2.714	1.581	--	.36
Calcined Clay	3	.46	.48	.52	.52	.80	.76	1.185	1.059	.26	--
Peat - Clay 1.8% 4.5%	1	.46	.47	.54	.53	.80	.76	1.116	1.143	.27	.31
Peat - Clay 3.4% 8.6%	2	.46	.47	.54	.53	.82	.84	1.167	1.217	.30	.32
Peat - Clay 6.1% 15.3%	3	.48	.42	.52	.58	.76	.80	1.095	1.451	.21	.29
Peat - Clay 1.7% 12.5%	2	.38	--	.62	--	.79	--	1.632	--	.33	--
Peat - Clay 6.3% 4.4%	2	.41	--	.59	--	.76	--	1.464	--	.28	--
Peat - Clay 2.2% 11.3%	2	.45	.48	.55	.52	.87	.81	1.202	1.147	--	.29
Peat - Clay 4.7% 5.7%	2	.45	.38	.55	.62	.88	.80	1.218	1.573	--	.30

(1) Portion (fraction) of the total pore volume that is capillary pore space.
(2) For exact proportions refer to Table 1.

landscape engineers latitude in prescribing soil conditioning treatments and developing suitable standard tests to determine soil needs.

Further study of the data in Tables 9, 10, and 10a and in Figures 6 and 7 shows that peat moss was about ten times as effective as calcined clay on a weight basis or five times on a volume basis in its effect on the void ratio. Table 9 summarizes the relative effects of the two soil conditioners shown in Figure 6 in terms of the change in void ratio per unit percent increase in weight of soil conditioner added to the soil.

Results of the laboratory study show the way water content of the soil is related to change in void ratio. Table 11 shows the average available water increase with increase in void ratio.

TABLE 11

AVAILABLE WATER ASSOCIATED WITH VOID RATIO

Treatment Level	Voids/Solids		Grams/Cubic Centimeter Available Water	
	Peat Moss	Calcined Clay	Peat Moss	Calcined Clay
0	0.88	0.88	0.25	0.25
1	1.37	0.98	0.34	0.29
2	1.87	1.16	0.33	0.30
3	2.16	1.12	0.36	0.26

The table indicates that peat moss is probably more effective than calcined clay in retaining water in an available form for plants.

Data from the field core study in Table 12 and 13 show the physical characteristics of the soils inside and outside the water saucer at the test plant sites. Trees and shrubs should show the influence of the backfill soil treatments in the early growth stage and in the rate of plant survival. Later growth characteristics should reflect the characteristics of the soils outside the water saucer more and more as seedling age increases. The data in Tables 12, 13, and 14 document the

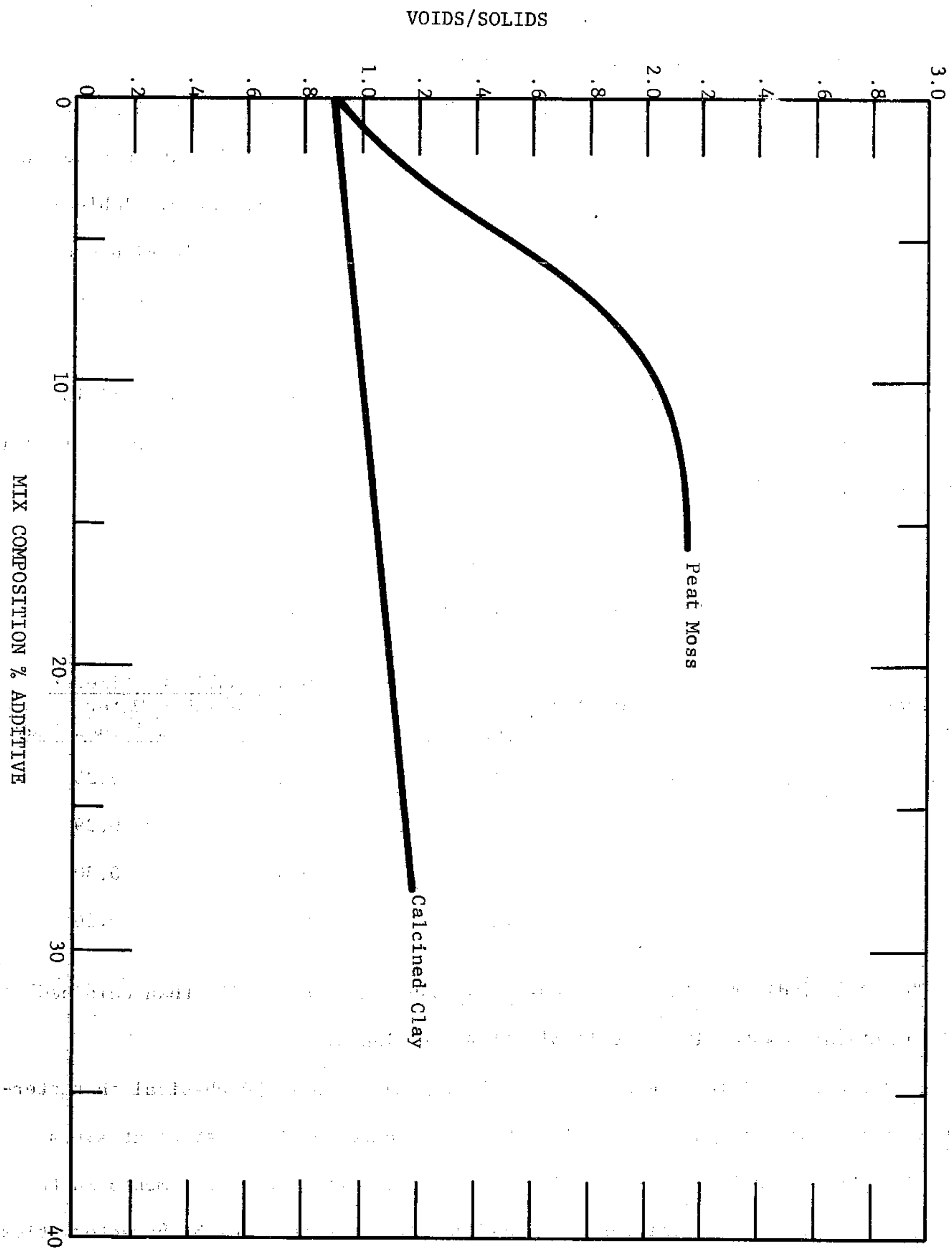


Figure 6. Effects of conditioners on void ratio

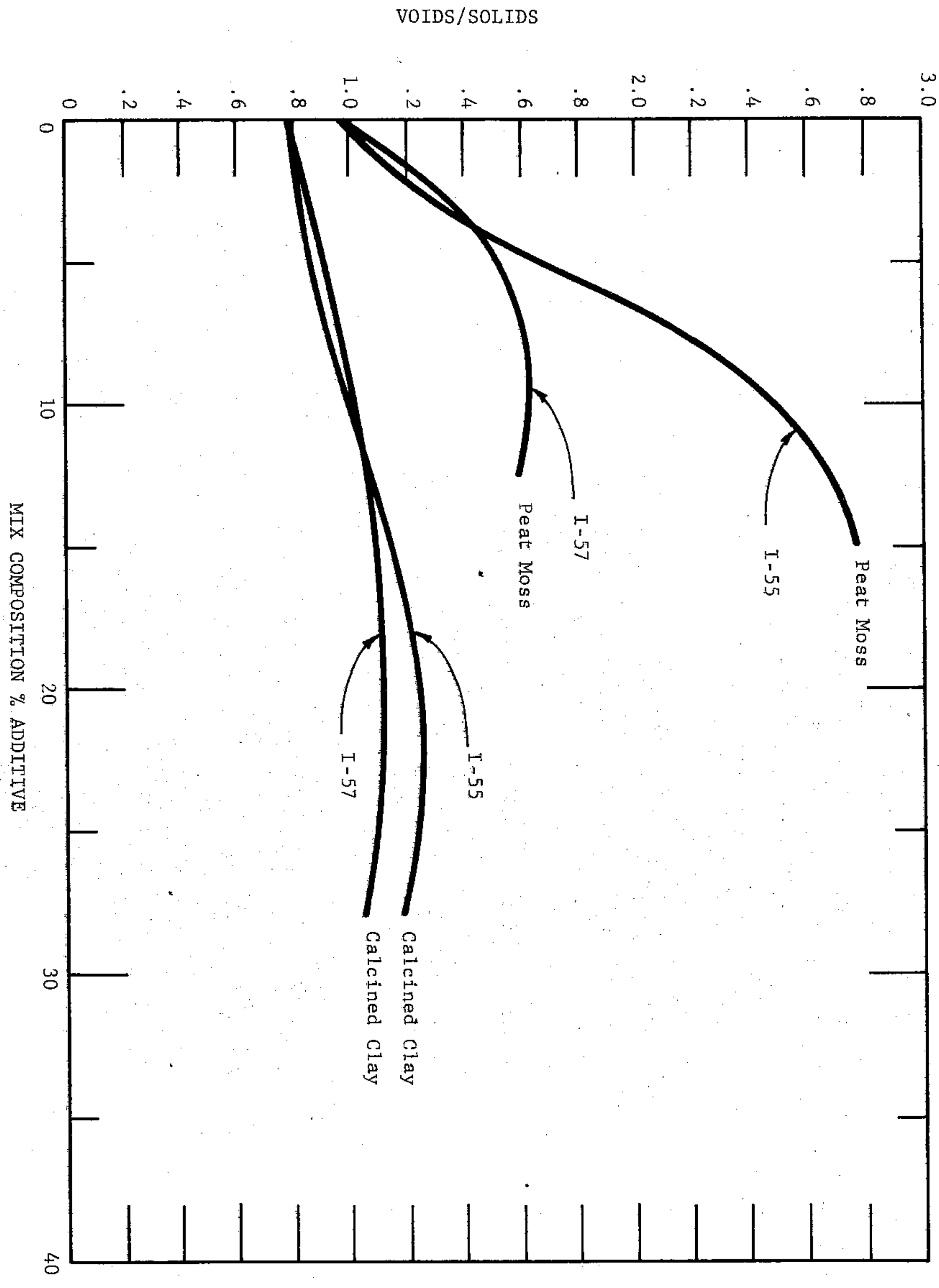


Figure 7 - Effects of sites and conditioner on void ratio

Table 12

PHYSICAL CHARACTERISTICS OF SOIL MATERIALS INSIDE AND OUTSIDE THE WATER SAUCER AT SELECTED PLANTING SITES IN TWO LANDSCAPE PROJECTS

Sample Site and Conditioners	Sample	Bulk Dry Density	PORE SIZE DISTRIBUTION				Available Water Storage cm/cm soil
			Solids Fraction	Total Pores	Micro Pores	Voids/Solids	
55 - 1E - Clay	Inside	1.20	.47	.53	.88	0.887	.18
	Outside	1.58	.58	.42	.87	0.697	.30
55 - 1W - Clay	Inside	1.19	.52	.48	.84	0.893	.26
	Outside	1.54	.59	.41	.82	0.747	.16
55 - 2 - Clay	Inside	1.22	.53	.47	.86	0.890	.15
	Outside	1.51	.60	.40	.87	0.649	.32
55 - 3 - Clay	Inside	1.16	.49	.51	.73	0.973	.24
	Outside	1.26	.41	.59	.86	1.548	.24
55 - 4 - Clay	Inside	1.30	.41	.59	.88	1.525	.18
	Outside	1.60	.45	.55	.91	1.257	.30
55 - 5 - Clay	Inside	1.30	.52	.48	.85	0.881	.27
	Outside	1.51	.57	.43	.87	0.751	.22
55 - 2 - Peat	Inside	1.12	.47	.53	.74	1.042	.23
	Outside	1.53	.62	.38	.84	0.740	.18
55 - 4 - Peat	Inside	1.11	.45	.55	.71	1.094	.22
	Outside	1.32	.59	.41	.80	0.692	.17
57 - 1 - Clay	Inside	1.29	.55	.45	.80	0.827	.23
	Outside	1.24	.49	.51	.73	1.019	.24
57 - 2 - Clay	Inside	1.45	.57	.43	.65	0.762	.22
	Outside	1.45	.55	.45	.77	0.821	.24
57 - 3 - Clay	Inside	1.23	.51	.49	.75	1.013	.29
	Outside	1.36	.52	.48	.77	0.974	.25

Table 12 (Continued)

Sample Site and Conditioners	Sample	Bulk Dry Density	Solids Fraction	PORE SIZE DISTRIBUTION Total Pores	Micro Pores	Voids/Solids	Available Water Storage cm/cm soil
57 - 4 - Clay	Inside	1.24	.50	.50	.75	0.996	.24
	Outside	1.46	.56	.44	.88	0.807	.25
57 - 5 - Clay	Inside	1.29	.43	.51	.75	1.066	.27
	Outside	1.40	.54	.46	.83	.878	.22
57 - 1 - Peat	Inside	1.19	.46	.54	.70	1.159	.25
	Outside	1.35	.53	.47	.76	0.982	.24
57 - 2 - Peat	Inside	1.37	.51	.49	.70	0.961	.24
	Outside	1.29	.51	.49	.72	0.966	.26
57 - 4 - Peat	Inside	1.15	.46	.54	.64	1.163	.22
	Outside	1.41	.53	.47	.79	0.876	.25
57 - 4 - Peat	Inside	1.29	.51	.49	.72	0.947	.24
	Outside	1.39	.56	.44	.79	0.776	.20

Table 13

CHEMICAL CHARACTERISTICS OF SOIL MATERIALS INSIDE (BACKFILL) AND OUTSIDE (BRIDGE CONES, ETC.) THE WATER SAUCER AT SELECTED PLANTING SITES ON INTERSTATE HIGHWAY LANSCAPING PROJECTS ON I-57 AND I-55

Site	Station	Drain-age	Veg.	Reaction (1) (PH)		Phosphorus (lbs/acre) (3) Available		Acid Soluble		Potassium (2)		Total C mg/ml
				Inside	Out	Inside	Out	Inside	Out	Inside	Out	Inside
57-1-Clay	5614 E	Normal	Pin Oak	6.8	6.1	26.5	20.2	48.0	27.2	H-VH	H	1.25
57-2-Clay	5652 E	Wet	Sycamore	6.0	5.7	59.5	14.8	121.5	22.8	VH	H	1.23
57-3-Clay	5446 E	Drouthy	Scotch Pine	6.3	7.5	18.0	31.2	88.4	62.0	H-VH	H-VH	0.99
57-4-Clay	5611 C	Slopes	Fr. Sumac	6.7	6.7	35.6	21.6	74.0	31.0	VH	H	1.28
57-5-Clay	5582 E	Drouthy	Honey Locust	6.2	6.1	33.6	12.4	48.5	21.2	VH	H	1.18
57-1-Peat	5850 E	Normal	Pin Oak	6.4	6.3	31.6	16.8	63.0	22.0	H-VH	H	1.75
57-2-Peat	5928 E	Wet	Sycamore	6.3	6.4	118.5	84.0	196.0	131.0	VH	H	1.30
57-4-Peat	5835 C	Slopes	Fr. Sumac	7.3	5.8	36.8	24.4	67.0	38.6	H-VH	H	1.32
57-5-Peat	5933 E	Drouthy	Honey Locust	6.1	7.0	52.0	20.4	89.0	36.0	VH	M-H	1.76
55-1E-Clay	190/00 N	Drouthy	Honey Locust	5.8	8.0	58.5	5.4	85.5	16.4	VH	H-VH	2.90
55-1W-Clay	190/00 N	Drouthy	Honey Locust	5.6	8.3	42.0	10.6	50.0	26.4	VH	H-VH	3.08
55-2-Clay	144/70 N	Normal	Mt. Ash	5.0	7.6	38.0	9.2	47.0	79.0	VH	H	2.83
55-3-Clay	Ramp	Normal	Hawthorne	6.6	8.0	20.4	20.4	29.2	65.0	VH	H-VH	2.60
55-4-Clay	1170/80	Drouthy	Mt. Ash	5.6	7.9	24.4	14.6	29.4	84.0	VH	M/H	2.65
55-5-Clay	Ramp "B"	Wet	Russian Olive	7.4	8.0	27.6	45.5	35.2	125.5	VH	VH	2.45
55-2-Peat	NE Loop	Normal	Mt. Ash	7.0	7.7	15.3	10.3	26.6	47.5	H-VH	H-VH	2.87
55-4-Peat	24/00	Drouthy	Mt. Ash	7.0	7.8	214.0	17.9	309.3	56.0	VH	M/H	3.64

(1) Inside refers to Backfill within the water saucer at a plant site. Out refers to a composite sample at 4 or 5 locations around the circumference of a circle, 2-3 feet (.61-.91 meters) or more outside the water saucer.

(2) Potassium test results may be converted to pounds per acre (Kilograms per hectare) as shown below: Taken from Circ. 765 entitled "Potassium" by the University of Illinois College of Agriculture

Very High	200/	(224+)	Slight	91-120	(102-134)
High	181-200	(203-224)	Low	61-90	(68-101)
Medium Plus	151-180	(169-202)	Very Low	40-60	(45-67)
Medium	121-150	(136-168)			

(3) 1 lb/acre = 1.12 Kilograms/hectare

Table 14

PHYSICAL PROPERTIES OF TREATED BACKFILL AND SOILS OUTSIDE
THE WATER SAUCER AT SELECTED PLANT SITES OF TWO LANDSCAPE PROJECTS

Test Site	Perimeter	Percent Finer by Weight (1) #40	#60	#200	.005	.002	(2) L.L.	(3) S.G.
I-57 Backfill	Untreated	94.7	74.7	40.5	10.0	9.0	22.1	2.60
57-1-Clay	Outside			80.0	29.4	19.0	35.0	2.68
57-1-Clay	Inside			78.0	21.5	16.0	32.8	2.65
57-2-Clay	Outside			75.0	22.8	17.3	25.9	2.67
57-2-Clay	Inside			35.0	10.0	3.0	17.7	2.64
57-3-Clay	Outside			79.0	20.0	14.6	31.3	2.65
57-3-Clay	Inside			--	--	--	29.0	2.67
57-4-Clay	Outside			32.0	27.0	20.8	32.7	2.66
57-4-Clay	Inside			74.0	20.5	16.0	36.2	2.61
57-5-Clay	Outside			84.5	27.5	20.0	36.7	2.65
57-5-Clay	Inside			84.0	23.5	16.4	30.6	2.69
57-1-Clay	Outside			88.0	27.5	20.0	29.4	2.67
57-1-Clay	Inside			84.0	22.0	16.6	34.9	2.66
57-2-Clay	Outside			77.0	22.2	16.6	27.0	2.63
57-2-Clay	Inside			72.0	22.0	16.6	27.4	2.64
57-4-Clay	Outside			84.6	30.0	22.0	34.4	2.67
57-4-Clay	Inside			76.4	22.0	17.8	30.2	2.68
57-5-Clay	Outside			82.0	20.0	14.5	28.7	2.67
57-5-Clay	Inside			87.0	24.8	19.0	35.2	2.66
I-55 Backfill	Untreated	95.0	91.5	80.0	32.0	20.0	37.4	2.57
55-1E-Clay	Outside			64.7	42.0	32.0	36.2	2.73
55-1E-Clay	Inside			70.0	23.2	16.0	36.8	2.63
55-1W-Clay	Outside			71.0	37.8	23.0	36.2	2.71
55-1W-Clay	Inside			66.2	23.0	10.0	39.0	2.63
55-2-Clay	Outside			86.0	55.5	34.0	38.2	2.66
55-2-Clay	Inside			74.2	25.2	12.0	34.0	2.72
55-3-Clay	Outside			72.0	33.0	24.5	39.3	2.63
55-3-Clay	Inside			79.2	30.0	22.0	42.6	2.62
55-4-Clay	Outside			80.0	47.2	15.2	38.4	2.64
55-4-Clay	Inside			77.5	33.0	22.0	37.4	2.75
55-5-Clay	Outside			49.5	20.0	10.0	32.2	2.70
55-5-Clay	Inside			70.0	26.2	14.0	39.1	2.67
55-2-Peat	Outside			81.0	43.8	32.0	29.5	2.76
55-2-Peat	Inside			75.0	31.5	21.2	41.0	2.62
55-4-Peat	Outside			70.0	31.0	22.5	26.8	2.72
55-4-Peat	Inside			69.5	23.0	15.2	42.8	2.65

(1) Particle Size Distribution follows ASTM Standard Procedures (D422-63) except that a rotary mixer is used for dispersion instead of the apparatus described in D422-63. Soils were soaked overnight in hexamethaphosphate followed by 15 minutes dispersion in the rotary mixer. No correlative data is available comparison.

(2) Liquid Limit follows ASTM Designation: D423-61T

(3) Specific Gravity follows ASTM Designation: D854-58 (1965)

physical and chemical status of the backfill and the field soils at the test plant sites. In general, the field soils (soils outside the water saucer) at the I 55 project are more compact and have lower porosity than the I 57 soils. Pore space generally occupies less than 50 percent of the unit volume of the soils at both sites. Phosphorus and potash supplies in the soils seem to be adequate at almost all sites.

FIELD INVESTIGATION

Field Blending of Alternate Backfill Mixes

The Effingham project only will be discussed. The Cook County project was similar.

The calcined clay was delivered in hopper car lots of approximately 50 tons (45.4 tonnes) each. The topsoil source was in a small overflow bottom on the east branch of Green Creek adjacent to the Shelby-Effingham County Line on the east side of the FAI 55 right-of-way at approximately Station 5618 + 00. The topsoil was first loosened by plowing and disking to a depth of approximately six inches (13.4 cm). The truck loads of peat moss were field mixed with topsoil in the same manner at the project specification rate (Illinois Standard Specification rate) which was 3.5 cubic feet per cubic yard (.13 cubic meters per cubic meter).

The calcined clay was spread by trucks and an endloader to an approximate two-inch (5-cm) depth over a calculated and staked area of topsoil. See Figure 8 for a view of this procedure. The required fertilizer was spread by shovel from a flatbed truck.

Procedures used in blending the calcined clay with the topsoil after the calcined clay was spread over the area were

(1) disking repeatedly both lengthwise and crosswise with a tractor and mounted tandem disk as shown in Figure 9,

(2) plowing eight inches (20.3 cm) deep twice by a farm tractor and plow (Figure 10),

Figure 8. An endloader spreading the windrows of calcined clay.

Figure 9. Final spreading and initial blending by repeated disking.

(3) repeated disking by a tractor and a tandem disk (Figure 11 shows the resulting texture),

(4) stockpiling by an endloader on a farm tractor into stockpile No. 1 Figure 11),

(5) slicing off stockpile No. 1 by the front endloader and dumping into stockpile No. 2 (Figure 12),

(6) loading trucks from the stockpile with an endloader to give additional blending (Figure 13), and

(7) unloading the trucks at planting sites which appeared to give additional blending rather than any segregation (Figure 14).

The conveyor belt in the bottom of an old lime-bed truck was quite effective in the final blending and repulverization of the mixture. When a dump truck was used, the material tended to unload in large masses, but the hand shoveling to the individual augered holes have a final blending at the larger bedding areas (Figure 15).

Planting Procedure

Hand planting procedures placed the backfill quite uniformly around the balled roots.

Watering around the ball settled the backfill in the saucer.

Marking and Measurement of Plantings

The trees and shrubs at the test sites were marked with a band of paint about six inches (15.2 cm) above ground level. This band served as a reference for initial and follow-up diameter measurements. Diameters were calipered both perpendicular and parallel to the pavement edge. The diameters were also determined by taping the circumference at the painted band. Taping seemed to provide a greater precision and repeatability of the measurement.

Diameter and Tip Growth Measurements - First Year

The diameters of the plantings, which were initially measured in March 1966 on the FAI 57 location, were remeasured for first year annual growth in November 1966. Ten typical tip growth measurements were recorded at each site. See Tables 15, 15a, and 15b for a summary of these measurements and details for each site and specimen.

Figure 10. Blending calcined clay with desired quantity of topsoil by plowing eight inches deep twice.

Figure 11. Resulting texture of blended calcined clay, topsoil, and fertilizer after repeated disking by a tractor with a tandem disk harrow.

Figure 12. Stockpile No. 1 (right central) was further blended by slicing its edge with an end-loader and moving to stockpile No. 2.

Figure 13. Closeup view of the peat moss-topsoil mix stockpiles showing the friable nature of this mix when ready for loading on trucks.

Figure 14. The unloading gives blending rather than segregation of materials.

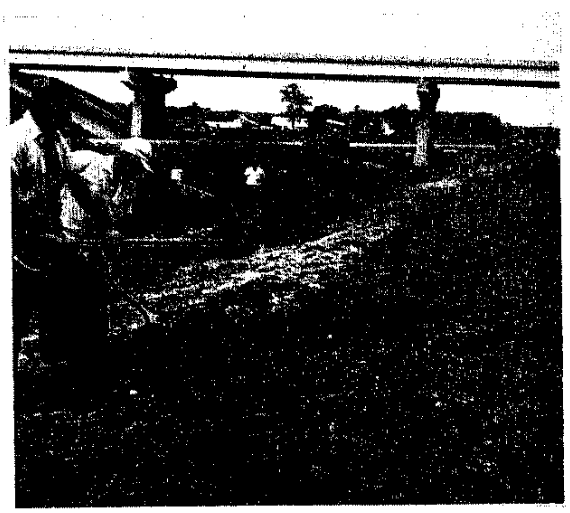


Figure 15. Final blending by hand shoveling mix into augered holes.

TABLE 15

FIRST YEAR GROWTH OF PLANTINGS AT SOIL SAMPLING SITES
Route FAI 57 North of Effingham, Section (25-8,87-1)LS
and Section (87-1-1,18-1)LS

Site Type			1966 Diameters in Inches (Average) (1)						Tip Growth in Inches (1)					
			Calcined Clay Sites			Peat Moss Sites			Calcined Clay Sites			Peat Moss Sites		
Soil	Drainage	Species	March	Nov.	Diff.	March	Nov.	Diff.	Low	High	Avg.	Low	High	Avg.
Natural	Normal Slope	Pin Oak	2.60	2.65	0.05	2.28	2.33	0.05	2	5	3.8	1	5	2.4
Ditch Cut in Natural Soil	Poor	Sycamore	2.60	2.63	0.03	2.20	2.25	0.05	2	9	5.3	1	3	1.8
Bridge Cones	Excessive	Pine	2.20	2.25	0.05	-	-	-	6	16	8.9	-	-	Dead
Bridge Cones	Excessive	Honey Locust	1.70	1.75	0.05	2.90	3.08	0.18	3	11	7.3	4	18	9.7
Median (Shrub Bed)	Inside Shoulder Slope	Fragrant Sumac	-	0.50	-	-	Dead	-	5	11	7.1	-	-	Dead

(1) 1 inch = 2.54 cm

TABLE 15a

MEASUREMENTS OF PLANTINGS AT SELECTED SOIL SAMPLING SITES
FAI 57 North of Effingham, Section (25-8,87-1)LS

Site Type		Calcined Clay Locations		1966 Diameters						Tip Growth	
				Calipered (inches)(1)				Taped at Painted Band		Low High (inches)(1)	Avg.
Soil	Drainage	Station	Species	Par. to Pavt. March 1966	Par. to Pavt. Nov. 1966	Perp. to Pavt. March 1966	Perp. to Pavt. Nov. 1966	March 1966	Nov. 1966	Nov. 1966	
1. Natural	Normal Slope	5614	Pin Oak	2	2.0	2	2.0	2.0	2.0	2-3-3-4-5	3.8
		5614	Pin Oak	3.25	3.25	3.25	3.25	3.2	3.30	3-4-4-5	
2. Ditch Cut in Natural Soil	Poor	5652	Sycamore*	3	3.0	3	3.0	3.0	3.05	2-4-6-9	
			Sycamore	2	2.0	2	2.0	2.2	2.20	2-3-7	5.3
		5652	Sycamore	-	-	-	-	-	-	-	
			Sycamore	2	2.25	2	2.25	2.0	2.10	5-6-9	
3. Bridge Cones	Excessive (S.W. Exposure)	5446	Scotch Pine	2.75	3.0	2.75	3.0	2.85	2.90	8-10-16	
		5446	Pine*	2.75	3.0	2.75	3.0	2.90	3.00	6-10-16	8.9
		5446	Pine	2	2.0	2.0	2.0	2.00	2.05	5-7-11	
	Excessive	5582	Skyline Honey Locust*	3.0	-	3.0	3.0	3.0	3.0	4-6-7 8-9	
			Honey Locust	1.50	1.50	1.50	1.75	1.70	1.75	3-6-9 10-11	7.3
4. Median (Shrub bed)	Inside Shoulder Slopes	5611	Sumac	-	.50	-	.50	-	-	5-8-11	7.1
			Sumac	-	.25	-	.25	-	-	5-6-9	
			Sumac	-	.25	-	.25	-	-	8-9-10	

*Soil sample site.

(1) 1 inch = 2.54 cm

TABLE 15b

MEASUREMENTS OF PLANTINGS AT SELECTED SOIL SAMPLING SITES
Route FAI 57 North of Effingham, Section (87-1-1,1B)LS

	Site Type		Peat Moss Locations		1966 Diameters						Tip Growth	
					Calipered (inches) (1)				Taped at		Low-High	Avg.
	Soil	Drainage	Station	Species	Par. to Pavt. March 1966	Par. to Pavt. Nov. 1966	Perp. to Pavt. March 1966	Perp. to Pavt. Nov. 1966	Painted Band March 1966	Painted Band Nov. 1966	(inches)	(1)
1.	Natural	Normal Slope	5850 East	Pin Oak	1.67	1.75	1.75	1.75	1.8			
				Pin Oak	3.50	3.50	3.50	3.50	3.5		2-3	
				Pin Oak*	1.67	2.0	1.75	1.75	1.75	1.80	1-2	2.4
				Pin Oak	1.67	1.75	1.50	1.75	1.6	1.7	1-2-3	
				Pin Oak	3.50	3.50	3.50	3.50	3.5	3.5	2-3-5	
2.	Ditch Cut in Natural Soil	Naturally poor but improved by grading	5928	Sycamore*	2	2.25	2	2.25	2.2	2.25	1-1-2	1.8
				Sycamore	2	-	2	-	2.0	-	2-3	
3.	Bridge Cones	Excessive (Conifer) (S.E. Exposure)	6035 to 6048	Austrian Pine - All three on slope dead	Replaced in 1967							
		Excessive (deciduous East Cone	5933	Shade-master Honey Locust*	3	3.0	2.75	3.0	2.8	3.05	4-6-7 8-18	9.7
		West Cone	5933 (S.W. Exposure	Honey Locust	3	3.0	3	3.0	3.0	3.10	7-9-11 13-14	
4.	Median (Shrub beds)	Inside Shoulder slopes	5833	Fragrant Sumac	Replaced in 1967							

*Soil sample site.
(1) 1 inch = 2.54 cm

The diameters of the plantings on the selected comparison sites on FAI 55 were initially measured on August 5, 1966, when planting on the control section was 65 percent completed. These were remeasured on January 5, 1967, when the tip growth measurements were taken. No significant increases in diameters were found. The tip growths were quite erratic. Some tips appeared to have taken a second growth late in the season; others appeared to have made an early thin growth in nursery or storage. See Tables 16, 16a and 16b for these measurements.

In general, field measurements of the selected planted stock during the establishment year indicated very limited diameter changes and quite erratic tip growth. The tip growth differences and mortality appeared more closely associated with plant species and site moisture conditions than with backfill differences. Tip development was found to vary widely on individual plants, apparently influenced by many factors such as bud damage and pruning. Thus the ten or more measurements appear needed at each site for a meaningful average tip development.

Diameter and Tip Growth Measurements - Subsequent Years

It was assumed that both the diameter and tip growth measurements would be more prominent and meaningful following the initial year of recovery from transplanting. However, the expectation that calcined clay conditioning of the backfill would have noticeably and measurably superior effects on growth during the establishment period was not borne out in this investigation.

After five growth seasons, excepting replacement plantings, the planted stock at the comparison sites was considered to be through the establishment period and into the development stage during which the roots were spreading and feeding beyond the backfill material.

The treated backfill materials may serve several purposes for a number of years, especially during critical periods. During droughts the infiltration and storage of occasional quick showers and the supply of nutrients by the backfill within the water saucer may be of significant value on adverse sites on slopes. There is also potential

TABLE 16.

FIRST YEAR GROWTH OF PLANTINGS AT SOIL SAMPLING SITES
Route FAI-55, S.W. Expressway, Section 0104-659LS
and Section 0407-656LS

Site Type			1966 Diameters in Inches (Average) (1)						Tip Growth in Inches (1)					
			Calcined Clay Sites			Peat Moss Sites			Calcined Clay Sites			Peat Moss Sites		
Soil	Drainage	Species	8-66	1-67	Diff.	8-66	1-67	Diff.	Low	High	Avg.	Low	High	Avg.
Clayey Fill	Side Slopes	Honey Locust	3.01	3.13	+0.12	Fall	2.92	-	3	12	5.5	Fall planted		
Natural and Sub-soils	Well Drained	Mountain Ash	2.26	2.31	+0.05	3.54	+3.50	-	5	12	8.1	14	18	13.0
Clayey Till	Poor	Thicket Hawthorn	1.41	1.34	-0.07	1.40	1.44	+0.04	1	7	4.0	3	7	4.5
Clayey Till Bridge Cone and Back Slope	Excessive	Mountain Ash	3.24	3.25	+0.01	2.97	3.02	+0.05	1	8	5.1	2	9	7.3

(1) 1 inch = 2.54 cm

TABLE 16a

MEASUREMENTS OF PLANTINGS AT SELECTED SOIL SAMPLING SITES - S.W. EXP.

	Site Type		Exposure to:		Calcined Clay Locations		1966 Diameters (1)			Fall 1966 Length (inches) (1) of Tip Growth	
							1-5-67 Calipered		Taped		
	Soil	Drainage	Salt	Sun	Station	Species	Par. to ℄	Perp.	8-5-66	1-5-67	Avg.
1.	Clayey Fill	Side Slope (Tube drains- 2 of 5 holes)	Runoff & spray	North	190 North	Honey Locust	3.0-	3.0-	2.98	12, 11	
							3.0-	3.0+	3.15	3, 3	
							3.0-	3.0-	2.81	3, 3	5.5
							4.5-	3.25+	3.38	3, 9	
							2.5+	3.0-	2.75	5, 3	
2.	Natural & Sub-soils	Well drained	Ramps only	South	145 North (NW Quad-rant)	Mountain Ash	2.25+	2.5-	2.29	6, 12	
							2.25	2.25	2.25	6, 11	8.1
							2.25+	2.5	2.31	5, 6	
							2.0	2.5	2.20	9, 10	
3.	Clayey Till	Poor	Ramps only	Flat	151 North (NE Quad-rant)	Thicket Hawthorn	1.50-	1.25+	1.35	3, 7	
							1.0-	1.0+	1.07	1, 2	4.0
							1.5	1.5	1.47	3, 7	
							1.5	1.5+	1.76	3, 6	
4.	Clayey Till Back Slope	Excessive	Normal	SW	1171 North	Mountain Ash	4.0	3.75	3.80	3, 8	5.1
							3.0+	3.0-	2.98	2, 6, 8	
							3.0+	2.75+	2.94	1, 6, 7	
5.	Median (Shrub bed)	Inside Shoulder Slopes	From both sides and bridge above	North and South	149-151	Russian Olive	(Cobs frozen around crown)		0.99---------below crown		
									1.72---------at crown		
									1.53---------below crown		
									1.34---------below crown		
									0.99---------below fork		

*Measured in order from east to west (in direction of adjacent traffic)

(1) 1 inch = 2.54 cm

TABLE 16b

MEASUREMENTS OF PLANTINGS AT SELECTED SOIL SAMPLING SITES - S.W. EXP.

	Site Type		Exposure to:		Peat Moss Locations		1966 Diameters (1)			Tip Growth (1) for 1966	
							1-5-67 Calipered		Taped		
	Soil	Drainage	Salt	Sun	Station	Species	Par. to ℄	Perp.	8-5-66	1-5-67	Avg.
1.	Clayey Fill	Side slopes	Runoff & spray	North	343+50 N (West of canal	Thornless Honey Locust	3.0	3.0	Fall planted	-	-
							2.75	2.75	Fall planted	-	-
							3.0	3.0	Fall planted	-	-
2.	Natural & Sub-soils	Well drained	Ramp spray only	South	322 S (Inside NE loop)	Mountain Ash	Dead	-	3.0	-	-
							3.50+	3.50	3.53	16,17	
										14,18	13.0
							Dead	-	Dead	-	
							3.50+	3.50	3.55	6,13	
										9,11	
3.	Clayey Till	Poor (Toe of slope)	Ditch Area from C-D	North	336 N	Thicket Hawthorn	-	1.55	1.53	3,4,4,7	
							1.25+	1.50	1.34	4,5	4.5
							1.25+	1.50-	1.38	5,6	
							1.50	1.50-	1.34	4,3	
4.	Bridge Cone	Excessive	Normal Lawn-dale Ave. & Ramp D	S.E. Over-looking GM&O RR	24+00 Lawndale Avenue	Mountain Ash	3.00	3.00	2.96	8,7,8	
							3.0+	3.12	3.09	2,3,10	7.3
							3.0-	3.0-	2.86	9,8,11	
5.	(Planting in median dropped because of salt concentration)										

(1) 1 inch = 2.54 cm

for improved drainage including leach out of deicing salt concentrations. The extent of these possible benefits for the conditioners can be determined only by continued observations during the developmental years.

Tables 17 and 18 summarize the five years of diameter and tip growths. These growths have been notably erratic with broad differences within most comparison sites. Therefore, differences within and between the sites need observations of condition variances to make the analysis more meaningful.

The chemical characteristics of the soil materials within and outside the water saucers, as shown in Table 13, were consistently high or very high in potassium and were generally satisfactory in available phosphorus for most species. However, the correlation between the locations of lower available phosphorus and lower rates of growth is not consistent.

There appears to be marked differences in the extent of damage from salt scald both by surface drainage and by the spray of brine from traffic. The mortality of most or all specimens at some sites is mute testimony of salt damage. The continuing evidence of salt scalded sod in these areas of high mortality substantiates the presence of this strong factor, especially along the expressway shoulders and on the side slopes of fill areas. The heavier salt burn of limbs and trunk bark of many trees on the side toward the pavement shows that the spray hazard puts limitations on species selection during design unless special shielding is provided at such sites.

The French style and tile underdrains from the root ball or water saucer area have proven not to be of sufficient help in leaching away salt concentrations from the critical conditions encountered on most side slope locations.

Perhaps a plastic or wax film protection of the trunk and an impermeable sheet over the saucer during the salting season of the establishment year might provide the margin needed in some situations. The contractors may find such special protections economically preferable to the costs of replacements.

TABLE 17

GROWTH OF PLANTINGS AT COMPARISON SITES
FAI 57 North of Effingham, Sections (25-8,87-1)LS and (87-1-1,18-1)LS

Soil	Site Type: Surface Drainage	Plant Species	Year	Diameter-Growth (1) in. (avg.) Calcined Clay	Peat Moss		Tip Growth (1) in. (avg.) Calcined Clay	Peat Moss
Natural Prairie	Normal Slope	Pin Oak	1966	0.05	0.05		3.8	2.4
			1967	0.23	0.18		6.4	6.2
			1968	0.47	0.44		9.0	9.7
			1969	0.55	0.22		9.8	3.2
			1970	0.55	0.10		8.3	8.8
			Total	1.85	0.99	Avg.	7.5	6.1
Ditch Cut in Natural Soil	Poor	Sycamore	1966	0.05	0.05		5.3	1.8
			1967	0.23	0.25		8.4	Dead
			1968	0.10	0.10		9.2	11.0
			1969	0.15	Dead		9.9	Dead
			1970	0.17	0.00		7.9	10.6
			Total	0.70	0.40	Avg.	8.1	7.8
Bridge Cone Fill	Excessive South Exposure	Honey Locust	1966	0.17	0.18		7.3	9.7
			1967	0.06	0.18		8.8	7.9
			1968	0.02	0.38		8.0	14.2
			1969	Dead	0.57		-	20.0
			1970	0.40	0.90		17.7	12.9
			Total	0.65	2.21	Avg.	10.5	12.9
Bridge Cone Fill	Excessive Southwest Exposure	Scotch Pine on Calcined Clay Austrian Pine on Peat Moss	1966	0.05	(Burned by grass fires)		8.9	-
			1967	0.50			6.1	3.7
			1968	0.90			9.7	-
			1969	1.00	0.10		14.6	2.6
			1970	0.40	0.20		9.0	7.4
			Total	2.65	0.30	Avg.	9.7	4.6
Median (Shrub bed)	Inside Shoulder Slopes	Fragrant Sumac	1966	-	(Many died first year)		7.1	6.0
			1967	0.25			11.3	10.6
			1968	0.25			10.4	8.3
			1969	0.05			12.4	14.5
			1970	0.20			10.4	13.4
			Total	0.75		Avg.	10.3	10.6

(1) **1 inch = 2.54 cm**

TABLE 18

GROWTH OF PLANTINGS AT SOIL SAMPLING SITES
Route FAI 55, Sections 0104-659LS and 0407-656LS, Cook County

Site Type: Soil	Site Type: Surface Drainage	Plant Species	Year	Diameter-Growth(1) in. (avg.) Calcined Clay	Diameter-Growth(1) in. (avg.) Peat Moss	Tip Growth(1) in. (avg.) Calcined Clay	Tip Growth(1) in. (avg.) Peat Moss
Clayey Fill	Side Slopes	Honey Locust	1966	0.12	(Fall planted)	5.5	(Fall planted)
			1967	0.10	0.05	8.9	8.2
			1968	0.18	0.11	6.5	8.5
			1969	0.09	0.02	4.5	3.1
			1970	0.20	0.20	8.4	4.8
			Total	0.69	0.38	Avg. 6.8	6.2
Natural and sub-soils	Well drained	Mountain Ash	1966	0.05	–	8.1	13.0
			1967	0.04	0.15	8.7	8.2
			1968	0.31	Dead*	13.6	9.4
			1969	0.04	0.25	7.8	11.0
			1970	Dead	Dead	Dead	Dead
			Total	0.44	0.40	Avg. 9.6	10.4
Clayey Till	Poor	Thicket Hawthorn	1966	0.07	0.04	4.0	4.5
			1967	0.01	0.02	7.2	11.0
			1968	0.18	0.05	8.8	12.1
			1969	0.28	0.05	3.0	13.2
			1970	0.10	0.10	14.2	14.9
			Total	0.64	0.26	Avg. 7.4	11.2
Clayey Till	Excessive Bridge Cone. and Slope	Mountain Ash	1966	0.01	0.05	5.1	7.3
			1967	0.10	0.01	15.8	2.5
			1968	0.34	Dead*	13.7	Dead
			1969	0.03		9.9	
			1970	0.18		16.1	
			Total	0.66		Avg. 12.1	

*The large differences for mountain ash may be largely due to the site and salt exposure differences. The calcined clay sites are on back slope cuts on the north side away from salt drainage or spray, whereas the peat moss sites are on side slopes where salt scald of sod is evident and the mountain ash specimen have died.

(1) 1 inch = 2.54 cm

CONCLUSIONS

The field experience with calcined clay versus peat moss as soil conditioners, together with the data obtained during the progress of the laboratory studies through May 1967, seems to warrant the following conclusions:

(1) Peat moss tends to increase available water holding capacity to a slightly greater extent than calcined clay, but calcined clay does a better job of maintaining or improving soil permeability. This latter factor is partially offset by the ability of the peat moss to expand on being wetted. The effects of this expansion on the feeding roots of trees and shrubs are not readily measurable. However, experience has shown that balled trees with peat moss treated backfill require brace wires to prevent tipping by wind during establishment months. The calcined clay mixed with topsoil provides a more stable backfill which may allow the elimination of such bracing.

(2) Both materials have the ability to modify the solids-pore space relationship. In this regard, peat moss is approximately ten times as effective on a weight basis and about 4.5 times as effective on a volume basis as calcined clay.

(3) Soil materials used as backfill differ in their needs for conditioning. One type of soil conditioner may be better adapted to meet the needs of one soil type than another.

(4) Calcined clay appears more long-lived in the soil, but this is partially offset by decreasing plant needs with time as the roots permeate out of the treated area into the surrounding natural field soil. Peat moss also serves as an energy source for organisms that provide plant food as it decomposes. The residual effects of peat moss as humus may be important also.

(5) A suitable standard test is needed to determine the treatment needs.

(6) The method used in this study could serve as a basis for development of a standard method for testing soils for soil conditioning needs. More reliable and more efficient equipment is desirable for standardized procedures.

(7) Voids/solids ratio is a measure of soil physical condition which, together with a ratio of coarse to fine porosity, could be helpful in preparing specifications. Voids/solids ratio, in addition to characterizing the soil, should be useful as a parameter for measuring the response of plants to variations in the physical character of soils.

RECOMMENDATION

Since the results of the study do not indicate that calcined clay is significantly better than peat moss as a soil conditioner, and, since the cost of the calcined clay treatment is substantially greater than that of an equivalent amount of peat moss, it is recommended that calcined clay not be used as a soil conditioner for routine landscaping projects.