DECOMPOSITION EFFECTS ON ENGINEERING PROPERTIES OF FIBROUS ORGANIC SOILS

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ABSTRACT

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Organic soil deposits are usually considered to be poor construction sites because of high potential settlement due to drainage and decomposition, and because of low stability. In the past these sites have been avoided, since more desirable locations were often available. With land in many areas becoming very expensive, organic soil deposits are being reconsidered for construction sites.

Research has been conducted on the engineering behavior of organic soils in Canada (MacFarlane, 1969), in Europe (Hanrahan, et al., 1967), and in the U.S.A. (Andersland, et al., 1971, 1974, 1975, 1979). Conventional soil mechanics theories for mineral soils have been applied to the analysis and design of foundations on organic soil deposits. Information on decomposition behavior of organic soils has not been available.

This research project has concentrated on decomposition and its effect on the relevant engineering properties of model organic soils prepared from pulp fiber and kaolinite. It has involved the development of new test procedures relevant to organic soils. A

procedure was developed and applied to induce decomposition of various combinations of Kaolinite and cellulose fibers under controlled laboratory conditions. A modified consolidation apparatus was introduced to minimize sample preparation time. Mathematical expressions have been derived for the volume (or height) of solids and consequently the void ratio as a function of decomposition. Since present methods for organic content determination could err by up to 15%, a new method was developed which reduced this error to less than 1%. A mathematically derived equation for the specific gravity of organic soils has eliminated most of the 18% error in current methods. An expression with decomposition as a function of organic content and cell yield has been derived. These improvements permitted consolidation and shear strength properties to be determined in terms of organic content, carbon to nitrogen ratio, and degree of decomposition.

A major break-through permits the ultimate settlement of undecomposed organic soils to be estimated on the basis of organic content and pressure. Using the experimental consolidation data and mathematically derived expressions based on the degree of decomposition, settlement determination of decomposing deposits can now be expressed in terms of initial void ratio, initial layer thickness, degree of decomposition, final void ratio, and a Ψ factor. Consequently, ultimate settlement predictions for organic soil deposits should now be much more reliable.

To the memory of my beloved father

To my wonderful mother and

To Zainab

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a = cross-sectional area of narrow bore tube

A = cross-sectional area of soil sample

a_v = coefficient of compressibility

C = cohesion

C = carbon

$C(T,D)$ = weight reduction coefficient

$C(P)$ = void ratio intercept parameter

Ca = calcium

C_c = compression index

C_α = coefficient of secondary compression

C_{CO} = initial compression index

C_{CI} = compression index after decomposition

C_v = coefficient of consolidation

D = diameter of vane

D = duration of burning

D_o = corrected initial dial reading

D_{90} = dial reading for 90 percent primary consolidation

D_{100} = dial reading for 100 percent primary consolidation

e = void ratio

E = modulus of elasticity

e_o = initial void ratio

e_I = void ratio after decomposition

f_e = fraction of substrate used for energy

f_s = fraction of substrate used for synthesis

Fe = ferric

G_S = initial specific gravity of organic soil

G_{SC} = specific gravity of clay

G_{SF} = specific gravity of cellulose

G_{SF} = specific gravity of organic matter

G_{SI} = specific gravity of organic soil after decomposition

G_{SM} = specific gravity of minerals

H = height of vane

H_0 = initial height

H_D = decomposed height

H_f = final height

H_F = height of cellulose

H_F = height or organic matter

H_S = height of solids

H_{SO} = initial height of solids

H_{SC} = initial height of clay

H_{SF} = initial height of cellulose

H_{SM} = initial height of mineral

H_{SI} = decomposed height of solids

i = integer

I = time interval

I_P = plasticity index

j = integer

k = coefficient of permeability

K_0 = initial coefficient of permeability

K_1 = efficiency factor

K_d = decay factor

K_I = coefficient of permeability after decomposition

L = length

LL = liquid limit

LL_0 = initial liquid limit

LL_I = liquid limit after decomposition

M = vane shear torque

m(P) = void ratio slope factor

M_C = molecular weight of cells

Mg = magnesium

MS = molecular weight of substrate

n = integer

N = nitrogen

Na = sodium

O = oxygen

P = phosphorous

P = stress

P_0 = initial stress

P_1 = stress level after a stress increment

PI = plasticity index

S_U = vane shear strength

S_{UI} = vane shear strength after decomposition

T = temperature

t_{90} = time required for 90 percent consolidation

t_{100} = time required for 100 percent consolidation

V = volume

ν_C = stoichiometric coefficient of cells

ν_S = stoichiometric coefficient of substrate

V_T = total volume

V_{SF} = volume of organic matter

W = weight

W_C = weight of clay or mineral

W_F = weight of cellulose or organic

W_r = percent of weight reduction

W_S = weight of solids

W_T = total weight

W_{CO} = initial clay or mineral weight

W_{CI} = clay or mineral weight after decomposition

W_{FO} = initial cellulose or organic matter weight

W_{FC} = cellulose or organic matter weight after decomposition

W_{FC} = weight of bacterial cells

W_{FP} = weight of decomposition by-product

W_{tl} = weight of nutrient free sample

W_{TO} = initial weight of ash analysis sample

W_{SI} = weight of solids after decomposition

X_C = clay or mineral content

X_F = cellulose or organic content

X_M = mineral content

X_W = water content, dry weight basis

X_{CO} = initial clay or mineral content

X_{CI} = clay or mineral content after burning

X_{DI} = percent decomposition

X_{FO} = initial fiber or organic content

X_{FI} = cellulose or organic content after decomposition

X_{WE} = equivalent water content

Y = McCarthy's cell yield coefficient

$\bar{y}$ = calculated cell yield (average value)

Φ = vane pointer rotation

ξ = load factor

ψ = height factor

σ_c = consolidation pressure

$\Delta\sigma$ = stress increment

ΔH = ultimate settlement

ΔH_C = consolidation settlement

ΔH_D = settlement due to decomposition

ΔH_α = settlement due to secondary compression

Δe = change in void ratio

ΔG_r = Gibb's free energy

CHAPTER I

INTRODUCTION

A. Background and Need for Study

Organic soils form in locations where plants and animals flourish. Their remains contribute organic matter to the soil in the form of plant and animal residues in various stages of decomposition. The organic soils in Alaska, Siberia, and Canada blanket large areas of landscape but are normally fairly shallow (a foot or two). The deeper organic soils are generally formed in some type of bog, either a swamp if it has trees or a marsh if it does not. Man-made landfills for organic wastes can also be classified as deep organic deposits.

In the past engineers have avoided organic soil deposits when constructing building foundations and highway embankments. High compressibility, the potential for decomposition, lack of adequate information on the mechanical behavior of these soils, and the availability of better sites, have been the major reasons. With an ever-expanding economy, the demand for land area makes it necessary that organic soil deposits be reconsidered as potential construction sites. The pressure to build using only the available technology and the legal liabilities of possible errors represent additional dimensions to the problems involving organic soils. This study has been directed to the influence which decomposition has on the mechanical behavior and

engineering parameters of fibrous organic soils. Current engineering designs for facilities on or in organic soils are often made without regard to the possible decomposition of the organic material present in these deposits. Since many properties of these soils appear to be related to organic content (Andersland and Charlie, 1975; MacFarlane, 1969) the potential exists for major stability problems with decrease in strength and significant amounts of consolidation settlement due to decomposition.

Research has been done on the engineering behavior of organic soils in Canada (MacFarlane, 1969) and in other countries. Studies on these soils included investigations of shear strength (Hanrahan, 1967) and consolidation behavior (Barden, 1968). Recent studies have dealt with the engineering behavior of man-made organic soils (Andersland and Matthew, 1973; Andersland and Charlie, 1975). Their research included investigations of permeability, Atterberg limits, consolidation, and strength characteristics of organic soils at various organic contents. The work indicated that the shear strength of a soil was increased by the addition of fibrous organic matter, this being attributed to fibers across the rupture surface acting as reinforcement and carrying tensile stresses. Their work also indicated that the shear strength increased with greater degrees of consolidation.

Decomposition of organic fibers could lead to larger settlements, loss of shear strength, and possible gas production due to biological action. MacFarlane (1969) stated that the gas content in peat deposits is of considerable theoretical and practical importance.

Laboratory and field measurements of pore pressure, permeability, and rate of consolidation, etc., are affected by the presence of gas. Natural organic deposits studied have been found to be generally stable unless loaded, disturbed, or the groundwater elevation changed. Samples taken from below the water table in muskeg showed little decomposition (MacFarlane, 1969). Samples taken from man-made organic deposits (papermill sludge) at various depths below the water table and representing ages from one to twelve years were examined using photomicrographs (Mazzola, 1969). No visual indication of decomposition was observed (Andersland and Charlie, 1975).

This lack of decomposition in present field deposits, man-made or natural, may be attributed to the following four factors:

1. The inhibition to decomposition of substances bound to clay (Grim, 1968; Imshenetsky, 1968; Lynch, 1956),
2. The absence of available nitrogen (Mazzola, 1969; Imshenetsky, 1968),
3. The lignin content of the fiber, and
4. The hydrophilic nature of cellulose.

Both anaerobic and aerobic biological organisms, responsible for the breakdown of organics, require a minimal source of nitrogen for the synthesis of new cell structure (O'Connor, 1961). Decomposition of cellulose becomes essentially inactive when the available nitrogen becomes less than 1.2% (Imshenetsky, 1968). The papermill sludges examined by Mazzola (1969) had available nitrogen at 0.0002 to 0.0005%. In recent years, to reduce the dissolved BOD of waste water, an accelerated aerobic biological activity is used before

the solids are settled out as sludges (Nemerow, 1971). Therefore, the possibility exists that some newer deposits of papermill sludge may have larger amounts of nitrogen than that reported by Mazzola (1969). The nutrient content of natural organic soils has not been reported in the literature. Therefore, the possibility exists that both man-made and natural organic soil deposits may break down at a greatly accelerated rate if nutrients are added. The nutrients in a natural soil could come from agriculture, seepage from septic drain fields, or from pollution from any source that contains nitrogen. Nutrients could be added purposefully to change the soil properties if the results could be predicted. The introduction of nutrients could also lead to possible unwanted gas production, settlement, and stability problems.

B. Nature and Objective of Study

It is evident that many gaps in our knowledge still exist and that decomposition effects for a variable C/N ratio, and decomposition effects for a fixed C/N on the engineering properties of organic soils is still unknown. Consequently this research was undertaken in three stages to help give a better understanding of organic soils.

1. Stage I

An extensive literature review was undertaken to determine ways of inducing decomposition in laboratory samples and to formulate appropriate methods for preparing and testing the soil samples. Waksman (1953) has shown that the C/N ratio is an important parameter

which must be controlled if decomposition is to occur. Three mixtures of cellulose fiber (30, 60, and 80% by weight) and kaolinite were used to prepare the organic samples. Ammonium chloride (nitrogen source) was added to a group of samples, using C/N ratios of 5, 10, 30, 50, 200, and ∞. These samples were subjected to anaerobic decomposition (absence of oxygen), in the mesophilic temperature range (38°C). To evaluate the effect of nitrogen source on the decomposition rates under the same environment, a second group of samples containing ammonium sulfate was used with C/N ratios of 5 and 10. Another group of samples containing 30, 60, and 80% cellulose by weight and ammonium sulfate as the nitrogen source were tested under aerobic conditions (oxygen present). Additional nutrients such as P, Na, Mg, Ca, and Fe were mixed with all samples.

Consolidation tests were conducted on all samples to provide information on the coefficient of consolidation c_v, compression index C_c, coefficient of permeability K, and the coefficient of secondary compression C_α. A miniature vane shear apparatus was used to determine the initial undrained shear strength of these samples at selected consolidation pressures.

2. Stage II

This stage involved tests on decomposed aerobic and anaerobic samples, two months from the preparation date. Data analysis was subsequently made, relative to decomposition, C/N influence, pH, and organic content. A comparison was made between the engineering parameters of decomposed and undecomposed samples. Concurrently, methods

were developed for monitoring organic contents, decomposition, specific gravity, and void ratio.

3. Stage III

In order to minimize nutrient effects on the general soil behavior, a fixed carbon to nitrogen ratio (C/N = 30:1) was used for the final sample group. This ratio, determined to be the most appropriate, allowed a stable and fairly fast decomposition rates irrespective of the initial organic content. These determinations were made possible through the use of data obtained in Stage II. The organic contents used were 30, 60, and 80% by weight so that a wide range of organic soils would be represented. Weekly tests were conducted for three weeks, after which most parameters were found to level off. Subsequent tests were run at two weeks. These tests included consolidation, vane shear strength, ash analysis, and pH, which permitted comparisons of several engineering parameters. Details on the three experimental stages with an analysis and discussion are given in subsequent chapters.

CHAPTER II

LITERATURE REVIEW

Considerable literature relating to organic soils is available, most of which has been directed toward the composition and mechanical properties of stable (nondecomposing) organic soils. The state of the art is poor in the area of unstable (decomposing) organic soils. Only limited research has emphasized decomposition of the organic soil fraction. Much of the available information is contradictory or confusing. Literature related to decomposition, decomposition rates, and its effect on the engineering parameters of organic soils are essentially nonexistent. This review covers the physical properties, decomposition, consolidation parameters, strength and elastic parameters of organic soils.

A. Physical Properties of Fibrous Organic Soils

1. Composition

Organic soils are formed chiefly in situ, either by the growth and decay of plants or by accumulation of fragments of inorganic skeletons. Inclusive in this category are the top soils including muskeg, marl, muck, and peat. Peat deposits are formed in the final stage of eutrophication. In this stage, vegetative growth is too thick and matted to permit complete decomposition. As a result, a fibrous organic deposit is formed in which much of the original plant material

is recognizable. A peat is highly compressible, black in color, and fibrous (Soper, 1927). The word humus designates the organic content in mineral soil. The determination of organic carbon and nitrogen in a soil reveals a carbon to nitrogen ratio which enables one to determine the stage of organic decomposition (Greenland, D. J., 1965). Waste-papermill sludges, which in addition to inorganic mineral content, also contain cellulose fiber mainly in the form of fines, may be expected to exhibit soil properties similar to an organic soil. In general organic soils have the following components:

1. Living macro-organisms--This includes plants, and plant roots,

2. Microbes or micro-organisms--A broad classification of these are bacteria, actinomycetes, fungi, algae, and protozoa,

3. Dead but identifiable remains of plants and animals--These are the input materials from which the humus is formed, and

4. Finely divided nonliving organic materials--These have been the object of much speculation regarding their precise origin. They are relatively resistant to decomposition. A large part of them are microbial remains and exudates.

Cellulose fiber sorption ability increases with relative humidity. This amounts to 12% by weight in ambient conditions, 30% by weight in a saturated atmosphere, and up to 200 to 300% by weight in water. Sorption of water brings about a swelling of the fiber with increased dimensions. Swelling results in a length increase of about 1%, diameter enlargement ranging from 15 to 20%, and volume increase of about 35%. In addition to the effect on ease of drainage, swelling increases the plasticity of a fiber. The individual factors affecting

swelling are only partially understood but include quality, quantity and degree of hemicellulose distribution, nature of the pulping process, and the type of organic additives added (Gallay, 1962). In the papermaking operation, a varying amount of fines is produced depending upon requirements of the grade, type of pulp, etc. An excess amount of this material will result in a decrease in drainage properties of the pulp (Rydholm, 1965). Since the greater portion of fibrous cellulose within the sludge is in the form of fines, it can be anticipated that the same drainage problem will occur.

Although cellulose and starch are polymers of the same building block, glucose, individual differences of the two polymers permit ready microbial attack on the latter while the former is more resistant to microbial and enzymatic breakdown (Alexander, 1961).

The physical properties of organic soils show a wide variation due to the type and origin of the organic matter. Mazzola (1969) examined sludge deposits from eight different mills for physical properties including water content, ash content, atterberg limits, vane shear strength, and a study to evaluate decomposition. MacFarlane (1969) conducted similar work on peat. Decomposition of the organic fraction in soil, if found could lead to large settlements, possible loss of shear strength, and possible gas production due to biological action. MacFarlane (1969) states that the gas content in peat deposits is of considerable theoretical and practical importance. Laboratory and field measurements of pore pressure, permeability, and rate of consolidation are affected by the presence of gas.

Samples from a sludge deposit taken at depths of 2 and 12 feet (0.61 and 3.66 m) and representing ages of 1 and 12 years were examined using photomicrographs (Mazzola, 1969). No visual indication of degradation was observed. This lack of decomposition was attributed to four factors:

1. The inhibition to degradation of microbial substances bound to clay
2. The absence of available nitrogen in papermill wastes effluent
3. The lignin content of the fiber, and
4. The hydrophilic nature of cellulose

Both aerobic and anaerobic biological organisms responsible for the breakdown of organics require a minimal source of nitrogen for the synthesis of new cell tissue (Eckenfelder and O'Connor, 1961). Decomposition of cellulose becomes essentially inactive when the available nitrogen becomes less than 1.2% (Imshenetsky, 1968). Mazzola (1969) estimated the available nitrogen for the sludge examined at 0.0002 to 0.0005%. In recent years, to reduce the dissolved BOD of the wastewater, an accelerated aerobic biological treatment, which requires the addition of nitrogen to increase biological activity, has been used before the solids are settled out as sludges (Nemerow, 1971; Koch and Lugar, 1958; Eckenfelder and O'Connor, 1961). Therefore, the possibility exists that some newer organic deposits may have larger amounts of nitrogen than reported by Mazzola (1969). Thus it can be concluded that decomposition may occur in sludges subjected to these new treatments. Nitrogen may also be supplied

through direct application, or made available by mixing the sludge with soil mixtures.

2. Consistency Limits

The consistency of a soil can be altered by increasing or decreasing the water content. The moisture contents associated with the passage from one state to the next are known as the Atterberg limits. The tests run for these limit determinations were developed through the work of Atterberg (1911) and Casagrande (1932). The consistency limits have become very useful for soil classification. The Atterberg limits (consistency limits) indicate the range of water contents (in percent of dry weight) for which a soil or sludge may be considered as a fluid, plastic, or solid. The liquid limit (W_L) is the water content at which the soil will flow and close a groove of standard width when jarred in a specified manner (ASTM D 423). The fibrous nature of most organic soils interferes with making the required groove cross section. The plastic limit (W_p) is the water content at which the soil begins to crumble when rolled into threads of a specified size (ASTM D 424).

Casagrande (1966) suggested that peat ranges from low plasticity for thoroughly weathered deposits to nonplastic for highly fibrous deposits. Organic soils fall below the "A" line on the plasticity chart as shown in Fig. 2.1. Casagrande suggested that, with an increase in fibrosity, the points on the chart move down and to the left.

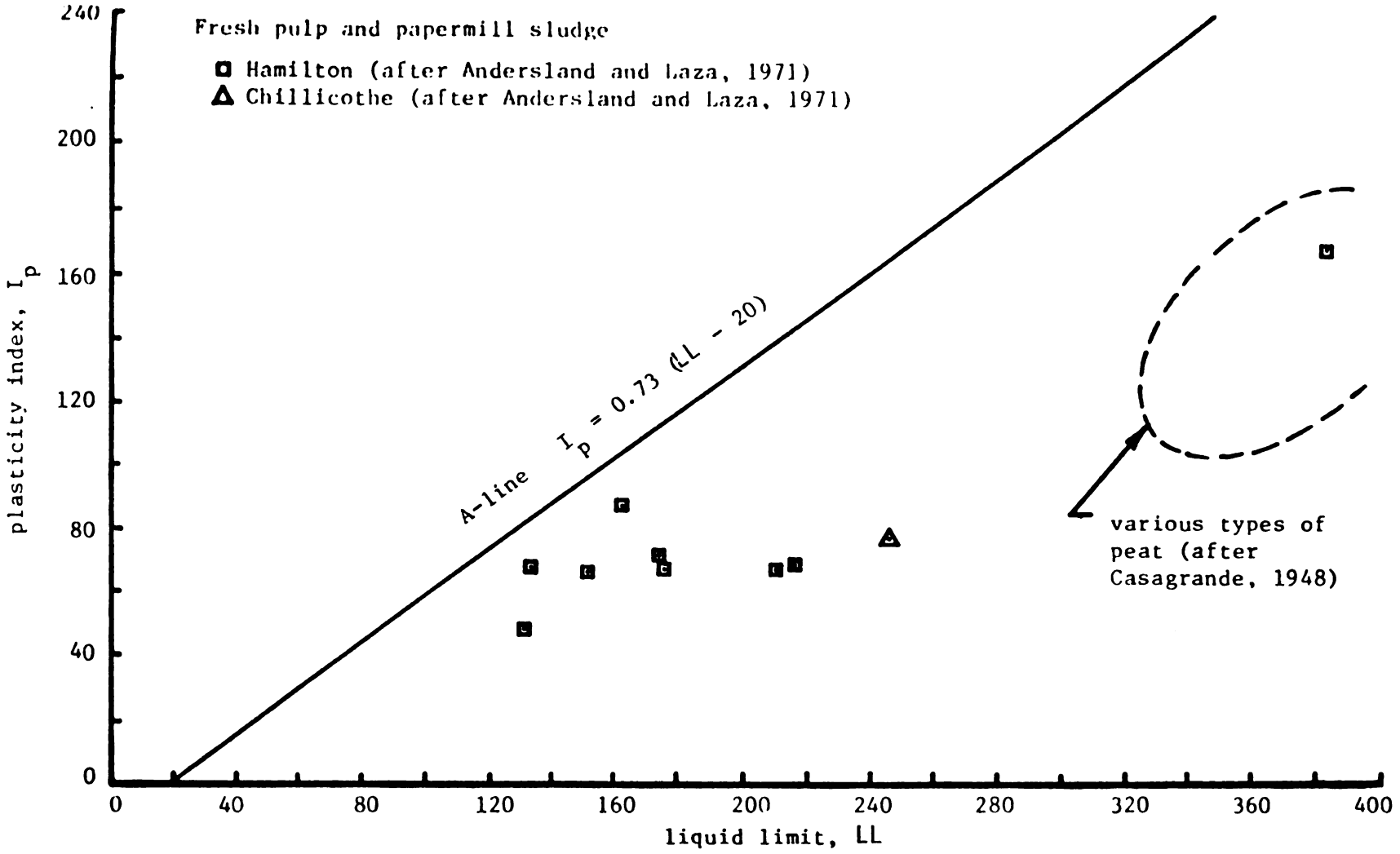


Figure 2.1.--Plasticity chart (Unified Soil Classification System) with data points for several fresh pulp and papermill sludges, (after Charlie, 1975)

Plastic and liquid limits of papermill sludges were found to be dependent on the ash content (Mazzola, 1969). These findings are in agreement with those reported by Vallee and Andersland (1974) for fresh papermill sludge and by Baver (1966) and MacFarlane (1969) for peat, muck, and similar highly organic soils. On Casagrande's (1948) plasticity index (W_L - W_p) vs liquid limit chart, the fresh sludge samples tested by Andersland and Laza (1971) fall below the "A" line as shown in Fig. 2-1.

Mazzola (1969) found that the water contents (W), for the field sludge samples tested, were greater than their respective liquid limits. The liquidity index ($W-W_p)/W_L-W_p$) for field sludge samples tested ranged from one to over 1000, with most of the deposits in essentially a fluid state. The consolidation potential for deposits with a high liquidity index is large since a high index indicates an unconsolidated material, which, when loaded will experience a large degree of consolidation. A high index also indicates that if the deposit is disturbed there will be a decrease in the shear strength, since remolding transforms the soil into a thick viscous slurry (Terzaghi and Peck, 1967).

3. Water Content

The amount of water contained in the voids of an organic soil in its natural state is called the natural water content. Organic soils have a high capacity for taking up and holding water; this affinity for water is one of the most important characteristics of the material (MacFarlane, 1969), and in its ability to soak up and hold water, organic soils act somewhat like a sponge.

The same drying temperatures as for mineral soils (105 - 110°C) are normally used in the determination of the water content of organic soils. There is evidence, however, that such high temperatures may actually char certain soil types (Goodman and Lee, 1962). Jackson (1958) suggests that the weight loss from drying at temperatures up to 100°C can be attributed to absorbed water, and that the weight loss due to drying at temperatures above 100°C can be attributed to water plus organic matter. Consequently, to reduce the hazard of burning off part of the organic matter, a drying temperature of less than 100°C is recommended, a temperature of 85°C being suggested as appropriate (Goodman and Lee, 1962; MacFarlane and Allen, 1964), particularly for fibrous peats.

Laboratory determination of the water content of peat is made in much the same way as for mineral soils. To obtain an average value of water content and to avoid local variations, a large representative sample should be used; a suggested minimum size for the sample is one that would contain at least 10 gm of dry solids. Drying to a constant weight at 85°C will be expedited by the use of a forced-draft drying oven, but even so will require two or three days for a large sample.

The quantity of water held in an organic soil varies considerably, being less for the more decomposed and amorphous types than the more fibrous types (Mazzola, 1969). In the pure peat range (averaging about 90% organic content), there is little relation between organic content and water content. For lower organic contents, however, there is an apparent linear relation, as indicated in Fig. 2.2 (MacFarlane, 1969).

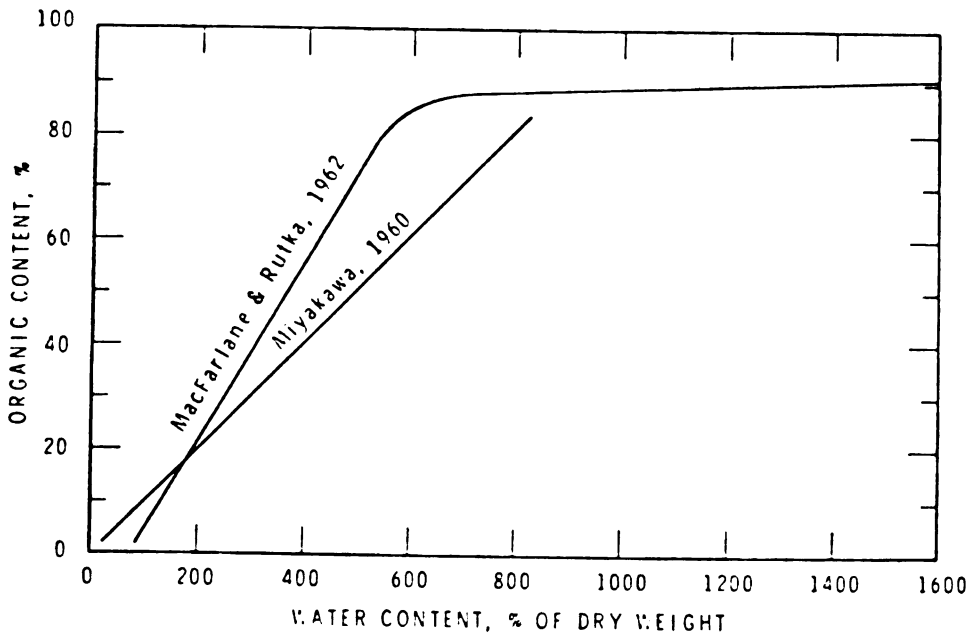


Fig. 2.2.--Organic content vs. water content (after MacFarlane, 1969).

4. Permeability

The permeability of organic soils is influenced by the physical structure and the arrangement of constituent particles, the permeability of such soils varies widely, depending upon:

1. The amount of mineral matter present, or the organic content,
2. The degree of consolidation and saturation,
3. The extent of decomposition.

Colley (1950) and Miyakawa (1960) have reported that the horizontal permeability of organic soils is generally greater than that in the vertical direction. Although organic soils are generally assumed to be quite permeable, many peat types are, in fact, relatively impermeable. This characteristic has long been recognized in Norway, where peat has been used as part of the impermeable core for rock dams (Tveiten, 1956).

The coefficient of permeability (k) of saturated organic soils can be measured in the laboratory with a variable head permeameter, in which the flow of water is metered at the inflow end. If h_1 and h_2 are the heights of the free water level in the inflow tube at time t_1 and t_2 respectively, k is given by the equation

$$K = 2.303 \frac{aL}{A(t_2-t_1)} \log_{10} \frac{h_1}{h_2} \qquad (2.1)$$

where a and A are the respective cross-sectional areas of the narrow bore tube and the organic soil sample, and L is the length of the

sample. The permeability can also be found from the consolidation test (MacFarlane, 1969).

The permeability of organic soils does not remain constant under pressure but decreases markedly for all types. An example of the effect of consolidation on permeability has been given by Hanrahan (1954), who loaded a specimen of partly humified peat with a natural void ratio of 12 and initial permeability of 4×10^{-4} cm/sec. After two days under a load of 8 lb/in^2 (0.56 kg f/cm^2) the void radio was reduced to 6.75 and the permeability to 2×10^{-6} cm/sec. After seven months under the same load, the void ratio was reduced to 4.5 and the permeability to 8×10^{-9} cm/sec. or 1/50,000 of the initial permeability.

Permeability values found in the literature vary from 0.03 to 10^{-7} cm/sec. depending on the organic soil under consideration (MacFarlane, 1969).

Although the permeability of peat is influenced by other factors such as gas, organic content, and source of organic matter, little is known about them. Published data on the effect of organic content on the coefficient of permeability (Andersland and Laza, 1971), is summarized in Fig. 2.3.

5. Organic vs. Inorganic Soils

Research on the engineering behavior of organic soil (MacFarlane, 1969) has placed little emphasis on defining these soils. The logical question to ask is, what percentage of organic matter is needed to make a soil organic and then how do we define organic

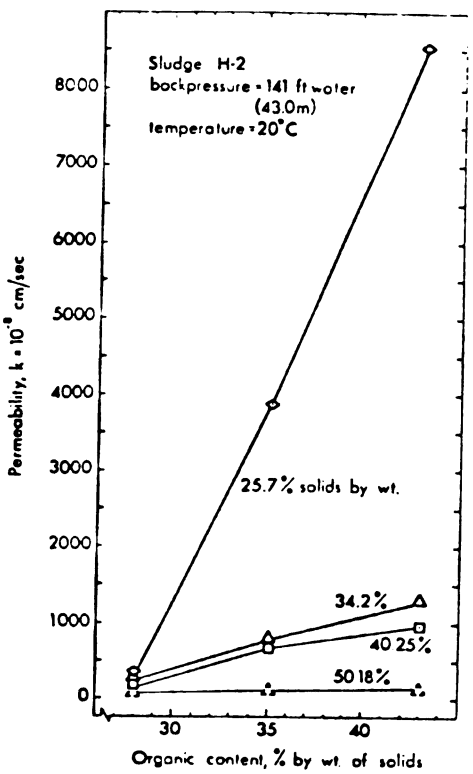


Fig. 2.3.--Organic content vs. permeability (after Andersland and Laza, 1972).

content? Very few scholars have attempted to answer these questions directly. Mokma (1960) stated that a soil is considered to be organic if the organic content exceeds 30% of the total sample dry weight. Bear (1964) defines organic soils as those that contain enough organic material to dominate the engineering properties of that soil.

Organic matter has been defined as anything that burns at a temperature greater than 100°C (Lamb and Martin, 1956). Others contend that steel can be burned under a controlled environment and clay loses varying amounts of its adsorped water at different temperatures. A more scientific definition is offered by Eastman (1978) which states: organic matter is anything that contains carbon with the exception of carbon dioxide and its dissociation species, bicarbonate and carbonate.

6. Gas Content

Organic soil below the water table is not entirely inert, but undergoes a very slow decomposition, accompanied by the production of marsh gas (methane) with lesser amounts of nitrogen and carbon dioxide. In deposits containing sulphur, hydrogen sulfide is another characteristic product of decomposition. When the water table is lowered, oxidation of the organic matter occurs, with the subsequent release of carbon dioxide.

The gas content is of considerable theoretical and practical importance. All physical soil tests are affected by it and, in the field, permeability, rate of consolidation, measurements of pore pressure, etc., are all believed to be substantially affected by the presence of gas (Lea and Brawner, 1963).

The effects of gas in organic soils show up particularly in consolidation results. In a laboratory consolidation test, a large initial compression and an indistinct completion of primary consolidation in time-compression curves reflects the presence of gas (Moran, et al., 1958). The effects on the time-compression curves are similar in appearance to secondary compression and some of the large secondary compression in peats and organic soils may be due to the presence of gas.

The gas content in organic soils is difficult to measure and no widely recognized method is yet available. The gas content, when determined, is obtained from data procured during the consolidation test. Moran, et al., (1958) report a free gas content of peats of 5 - 10% of the total volume of the soil at atmosphere pressure. Lea and Brawner (1963) similarly report a gas content of 7 - 10% for Vancouver, B.C. peats.

The presence of marsh gas may be a cause for concern when buildings or fills (for parking lots, etc.) are built on a peat bog. The possibility of marsh gas escaping through fissures, holes, or borings and burning upon union with atmospheric oxygen is reported by Moran (1958).

7. Specific Gravity

The specific gravity of organic soils varies considerably from one site to another, the range is reported to be from 1.1 to 2.5, with the average being 1.5 to 1.6. Specific gravity values greater than

2.0 indicates a peat with a considerable degree of mineral contamination (MacFarlane, 1969).

Accurate determination of the specific gravity is somewhat difficult due to the presence of entraped air or gases. This can be overcome by pulverizing the oven dried sample with a mortar and pestle. The specific gravity can then be measured in the usual way by the liquid displacement method. Water can be used, but more accurate results are achieved by using kerosene with a known specific gravity. A satisfactory experimental procedure for determining the specific gravity of organic soils is outlined by Akroydo (1957).

An approximate and more rapid method of determining the specific gravity of peat has been suggested by Cook (1956) and Lea and Brawner (1963). They used the concept of ash content (minerals), assuming that the ash is composed of clay minerals with a specific gravity of 2.7 and that the organic material (liquid and wood) burnt off during the firing has a specific gravity of 1.5. The average specific gravity of the peat solids is then calculated from the equation

$$G_S = (1 - X_m)\ 1.5 + 2.7\ X_m \quad . \qquad (2.2)$$

where X_m is the ash (mineral) content. Doyle (1963) has estimated that these assumptions can result in an error of 18% in an extreme case.

B. Decomposition of Organic Soils

The organic fraction of soil is a complex of substances whose composition is determined in part by the plant and animal

residues added to the soil, and to a greater extent, by transformation of these substances through biological, physical, and chemical means. Decomposition is the process by which micro-organisms return animal residues and plants to the soil. As a result of these microbiological processes, the elements which were originally consumed by plants for organic synthesis are returned to circulation.

The decomposition process is a very slow one. It takes place over a period of time, and it can be divided into two distinct types:

1. Chemical decomposition--it occurs in a medium where the temperature is greater than 85°C,
2. Biological decomposition--it occurs in a medium where the temp. is between 0 and 85°C in the presence of water and a reasonable amount of nitrogen and carbon. It is divided into two distinct types, aerobic and anaerobic

1. Soil Components Involved

Soil contains living and dead organic materials of plant and animal origin ranging in size from submicroscopic particles to the largest tree roots. The following components are considered significant from the point of view of mode of origin.

a. Living macro-organisms.--They are the source of all soil organic matter and thereby indirectly influence many soil properties. These living entities also have other, more direct ways of influencing the soil behavior. Plant roots, for example, move soil particles as they penetrate the soil and grow in size. This rearrangement changes the size and shape of soil beds. Later when the root dies and decomposes, the temporary channel left in the soil serves as an aeration pore space.

b. Dead but identifiable remains.--Plant and animal remains are the input materials from which humus is formed. The amount present in the soil varies from time to time, according to the season of the year. Some changes in the material take place very rapidly, such as the leaching of soluble ions. Decomposition begins almost immediately and builds up to a maximum rate within a few days or weeks if conditions are favorable. Full decomposition, however, normally takes months or years and may even extend to many centuries in some soils that are so wet that oxygen is virtually excluded.

c. Microbes or micro-organisms.--The microbial population of the soil includes large numbers of microanimals and far larger numbers of microplants. The latter is referred to as microflora. The number of varieties of microbes occurring in soil is much too large for any detailed consideration here.

d. Finely divided nonliving organic material.--The finely divided nonliving material has been the object of much speculation regarding its precise origin. It is relatively resistant to decomposition. A large part of it is microbial remains and exudates, but there may also be exudates from plant roots, earthworms, etc. Finely divided nonliving materials are major components of soil humus. They tend to coat the mineral particles of the soil and are especially associated with clay. Their small size is a contributing factor to the dark color that humus imparts to soil.

2. Decomposition Types

Decomposition is a biological process for converting organic solids into a stable, humus-like product. The term "decomposition" is used instead of "stabilization," because in practice, the process rarely is carried to the point at which the organic fraction is completely stabilized.

a. Aerobic decomposition.--Aerobic decomposition or composting of organic materials involves the activity of aerobic microbes, and hence the provision of oxygen during the decomposition process. Aerobic decomposition is generally characterized by high temperatures, the absence of foul odors, and is more rapid than anaerobic decomposition.

Aerobic decomposition (composting), very similar in action to a sanitary landfill, is a controlled microbial reaction yielding a stable product much sooner. The purpose of composting is to remove the readily degradable organic matter from the refuse and to produce a stable material that can be used to recover waste land or to grow food crops. In areas of the world where the population per unit of land mass is very high, such as in Japan, China, and India, composting of refuse is practiced to recover the nutrients as fertilizer. In the countries rich in mineral fertilizers, composting has never been practiced to any extent. In the U. S. composting has never been successfully used on a large scale for a long period of time. As the need for waste-land recovery increases, there will be greater emphasis on composting.

Two types of composting have been used thus far: the open windrow and the mechanical. The open-windrow method consists of placing the refuse in piles approximately 4 ft. high and 8 ft. wide. The moisture content of the compost is adjusted to approximately 60% and biological activity is allowed to begin. After several days the waste heat from the microbial reactions increases in the compost pile and the microbial population shifts from mesophilic to thermophilic reactions as temperatures rise to 70°C. The pile is turned before the temperature rises too high and the moisture content adjusted to 60%. Turning of the pile permits cooling and assists in aerating the pile so that the matabolism remains aerobic. The temperature of the pile will once again rise to 70°C and the pile must be turned again. After several turns the temperature will fail to reach 70°C and begins to drop off. Failure of the compost to increase in temperature has been used as the criterion for determining that the compost has been stabilized. The open-windrow composting process takes approximately six to ten weeks for completion.

The mechanical system uses mechanical devices for continuously turning the compost, adjusting the moisture content, and adding air. Although the mechanical devices are all propriety devices, they operate on the same principles as the windrow composting. The only difference is the fact that the time required to produce the stable compost is only three to six days.

The operational problems associated with aerobic decomposition are fewer than those of anaerobic digestion (McKinney, 1962). Hence,

less laboratory control and daily maintenance are required. Also, the dangers of gas explosions are eliminated because the only gaseous by-products of aerobic digestion are carbon dioxide and water vapor.

In aerobic digestion of organic materials two different forms of oxidation take place, as shown in the following two reactions.

$$\text{Organic matter} + O_2 \rightarrow \text{cellular matter} + CO_2 + H_2O$$

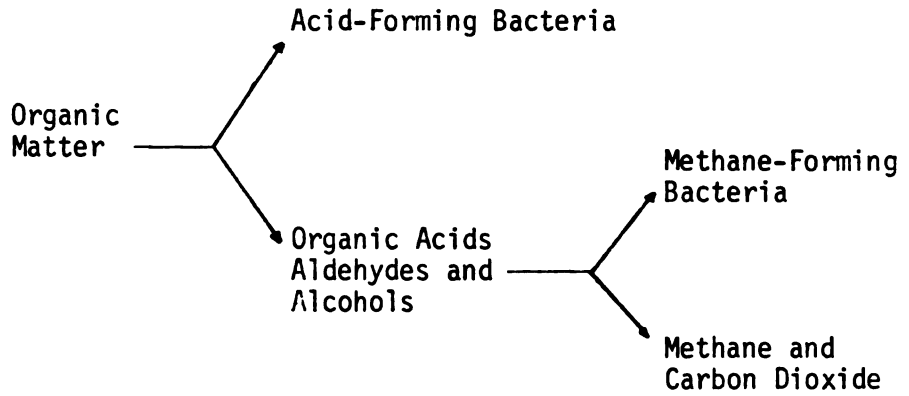
$$\text{Cellular matter} + O_2 \rightarrow \text{digested organic matter} + CO_2 + H_2O$$

First, a portion of the organic substrate in the sludge is oxidized and the remainder is converted to cellular matter. Second, the cellular matter produced is oxidized until only a relatively inert fraction remains.

b. Anaerobic decomposition.--This type of degradation involves the activity of anaerobic micro-organisms, and hence the exclusion of oxygen during the decomposition process. It is a slow process in comparison with the aerobic process. It is characterized by low temperatures (unless heat is applied from an external source) and the production of odorous intermediate (reduced) products.

When the anaerobic process has been carried to its full extent, the major end products are synthesized cellular material, the metabolic waste products methane and carbon dioxide, and a residue of nondegradable material. The anaerobic conversion of organic materials to methane can be separated into three steps: (1) Hydrolysis, in which

large complex organic molecules are enzymatically broken down into smaller molecules capable of being transported into the cell; (2) acid fermentation, which is the intracellular conversion of smaller molecules into a variety of organic materials of which the most important are short chain volatile acids; and (3) methane production, or the conversion of short and long chain organic acids to methane. McKinney (1962) gives a schematic representation of the acid and methane phases as shown below.



The amount and type of organic acids produced in the acid fermentaion step of anaerobic decomposition depends on composition of the organic matter. The three most abundant classes of degradable, natural, organic compounds found in organic soils are proteins, carbohydrates, and lipids. Protein and carbohydrates, once solubilized, are readily fermented to volatile acids. On the other hand, only minor changes occur in the lipid fraction during the hydrolysis and acid phases. Major reduction of this fraction occurs only during the methanogenic phase. Most of the work on anaerobic digestion has

naturally concentrated on the methanogenic phase. This phase has been shown to be the overall rate limiting step in the digestion process (O'Rourke, 1968).

The anaerobic decomposition process is summarized by the following equations for simple carbohydrates such as glucose.

$$C_6H_{12}O_6 \xrightarrow{\text{Acid Formers}} 3CH_3COOH$$

$$3CH_3COOH + 3NH_4HCO_3 \longrightarrow 3CH_3COONH_4 + 3H_2O + 3CO_2$$

$$3CH_3COONH_4 + 3H_2O \xrightarrow{\text{Methane Bacteria}} 3CH_4 + 3NH_4HCO_3$$

These equations are equally applicable to digestion of sludge.

A dynamic equilibrium between buffer formation and destruction is maintained when the anaerobic decomposition process is proceeding satisfactorily, i.e., the methane bacteria will convert the volatile acids produced by the acid former at a rate such that the pH is maintained at a favorable level. However, when an upset occurs, it is usually the methane bacteria rather than the acid formers which are adversely affected. Therefore, net buffer consumption takes place, and the process is in danger of pH failure. When this occurs, an external source of alkalinity, such as lime, must be added to maintain the pH in the proper range.

3. Factors Influencing Aerobic Decomposition Rates

Since the aerobic decomposition process is essentially a biological one, rate controlling factors in the process are those influencing biological activity in general, namely, environmental factors. In fact, organism-related factors are perhaps the ultimate rate limiting factors, because they determine the rate of growth and degree of activity of the microbial population, and hence, the rapidity and nature of the compost process. The principal environmental factors in aerobic decomposition are moisture, temperature, pH level (hydrogen ion concentration), nutrient concentration and availability, and oxygen concentration (Golueke, 1973).

a. Micro-organism types.--Genetic traits of micro-organisms, while not an environmental factor, constitute the ultimate rate limiting factor. The significance of this statement, regardless of how close the optimum environmental conditions may be, is that the rate of decomposition depends upon the capacity of micro-organisms to break down the organic matter. This capability of the micro-organisms depends upon their genetic make-up; and the environment permits the expression of this genetic make-up.

A practical aspect of genetic limitations is that no amount of sophistication of equipment will hasten the decomposition of resistant materials beyond the limit permitted by the genetics of the organisms involved. Another practical aspect is that maintaining environmental conditions beyond the optimum level is a waste of effort, inasmuch as

the potential as determined by the genetics of the organisms cannot be surpassed.

University of California studies of aerobically decomposed organic materials showed that, facultative and obligate aerobic representatives of bacteria, fungi, and actinomycetes were encountered. Bacteria were characteristically predominant at the start of the process, with fungi appearing in 7 to 10 days, and actinomycetes becoming conspicuous only in the final stages. Bacteria were found in all parts of a pile, whereas actinomycetes and fungi were confined to a sharply defined outer zone, beginning just under the surface of the pile. In most cases, the population of fungi and actinomycetes was great enough to impart a distinctly grayish-white appearance to this zone. The limitation of these two groups to the outer zone probably was a function of either temperature or aeration.

b. Carbon/nutrient ratio.--To keep reproducing and thus bring about decomposition, all micro-organisms, indeed all organisms, must have a minimum supply of all of the elements of which their cellular matter is composed. One of the most important balances with respect to organic matter decomposition is the carbon-nitrogen balance (C/N ratio). Because part of the carbon is lost as CO_2 or CH_4 and depending upon the type of organisms, carbon is present in the cellular material in greater concentration than is nitrogen. The amount of carbon is approximately five times the amount of nitrogen.

The optimum C/N ratio range falls within 20-30 to one (McGauhey, 1953). The more the carbon-nitrogen balance deviates from the optimum, especially in the upper range, the slower the process proceeds. However, the actual upper limit for an individual application depends upon the degree of availability of carbon. If the carbon is present in a form highly resistant to bacterial attack, it is of little use to micro-organisms as a food source. Consequently for an organic matter than cannot be readily hydrolyzed, the carbon to nitrogen ratio is taken as 25:1 or even higher (Golueke, 1973). Soils which contain a heavy concentration of paper, fiber, wood, or straw can be classified as highly decomposition resistant.

The nitrogen concentration of a sample to be decomposed can be determined by the usual Kjeldahl method (Golueke, 1973). If access to equipment for carbon analysis isnot available, the carbon content can be roughly determined according to a formula developed by New Zealand researchers in the 1950's. The formula is as follows:

$$\% \text{ Carbon} = \left(\frac{100 - \% \text{ Ash}}{1.8}\right)$$

Researchers at the University of California have shown that the results obtained through this method approximated the more accurate laboratory determination of carbon within 2 to 10%.

Other nutrients, required in different proportions and dependent on the micro-organism make-up, include sodium, calcium, magnesium, iron, and phosphorus. Waksman (1953) studied the effects of the C/N ratio on

the rate of decomposition using 2% by weight organic soil, his findings are summarized in Fig. 2-4.

c. Temperature.--Temperature has long been recognized as one of the key environmental factors affecting biological activity. In general, each group of organisms has an optimum temperature, and any deviation from the optimum is manifested by a decline in growth and inactivity of the micro-organisms. Golueke (1973) gives three subranges of temperatures into which most micro-organisms are grouped. These include cryophilic, mesophilic, and thermophilic. The boundary temperatures for each range have been somewhat arbitrarily assigned as: 5°C to 10°C for the cryophilic range, 10°C to 40°C for the mesophilic range, and 45°C to 70°C for the thermophilic range. Certain blue-green algae and bacteria can survive and grow at temperatures as high as 80 to 90°C. The proponents of mesophilic aerobic decomposition claim that mesophilic bacteria are more efficient than thermophilic bacteria, and that decomposition therefore proceeds more rapidly. An important advantage claimed by the proponents of thermophilic range, in addition to improvement in the process, is that pathogens and weed seeds are killed at the high temperatures. This latter feature probably is one of the main reasons why most modern aerobic decomposition systems involve the thermophilic range at some stage in the overall process (Wyley, 1957).

The question of temperature probably is academic, since the temperature of a reasonably large or insulated mass will gradually rise

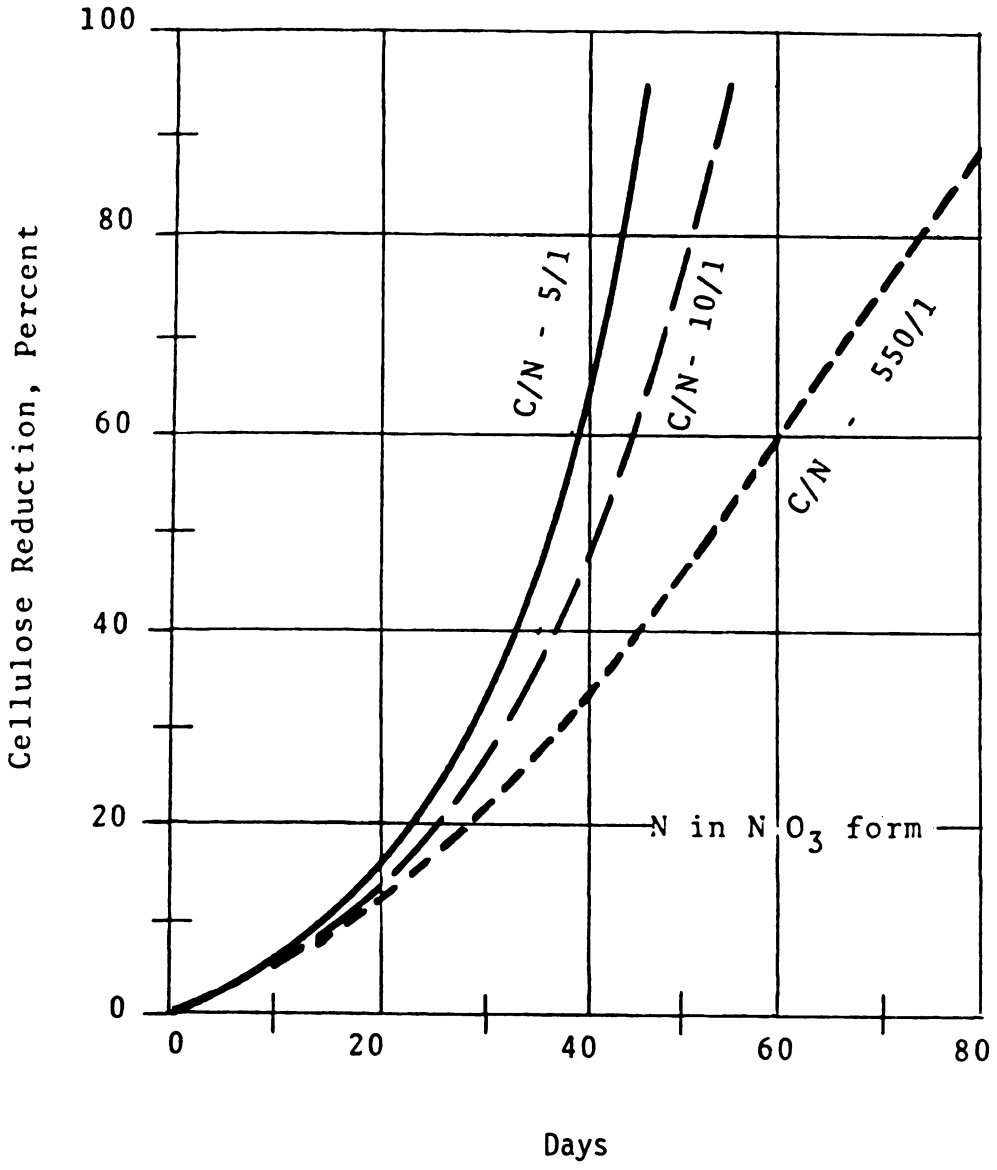


Fig. 2.4.--Cellulose reduction vs. time (after Waksman, 1953).

to well within the thermophilic range due to excess energy of microbial orgin. This increase will inevitably take place unless positive measures are taken to dissipate the heat.

There is no doubt that the aerobic decomposition process becomes less efficient when the temperature exceeds 60°C if for no other reason than the spore forming organisms begin to enter the spore or resistant stage at temperatures of 60°C and higher. In the resistant stage activity diminishes to practically zero and, hence, the process is correspondingly retarded (Schulze, 1961).

At one time it was thought that as far as bacterial activity was concerned, a kind of "no-man's" land existed between the end of the mesophilic range and the beginning of the thermophilic range. The reason for this was a supposedly sharp division of organisms into mesophiles and thermophiles. As for facultative organisms, it was thought that the alternative range was within either the strictly mesophilic or the strictly thermophilic ranges. However, studies by Allen (1953) on the temperature requirement of aerobic sporeformers showed that the "no-man's" zone was an artifact arising from the conditions under which the temperatures were determined, the prime source of error being the failure to use "adapted" or "acclimated" cultures.

At temperatures lower than 35°C, the efficiency and speed of the process increases when the temperature exceeds 30°C and approaches 35°C. The slope of a curve showing efficiency or speed of the process as a function of temperature would be practically a plateau between 35°C and about 55°C, with perhaps some declination between 50°C and

55°C. As the temperature exceeds 55°C, efficiency and speed begins to drop abruptly and becomes negligible at temperatures in excess of 70°C. At temperatures above 65°C, sporeformers begin to lose their vegetative forms and assume spore forms. In the spore form, very little activity takes place. Nonsporeformers simply die off.

d. Hydrogen ion concentration (pH).--Many of the reasons offered for the broad permissible temperature range apply to the pH level factor. As a generality one can state that fungi tolerate a wider range of pH values than do bacteria. The optimum pH range for most bacteria is between 6 and 7.5, whereas for fungi it can be between 5.5 and 8.0. In fact, the upper pH limit for many fungi has been found to be a function of precipitation of essential nutrients from the growth medium, rather than of any inhibition due to pH.

In a practical operation, little can be done, or rather, should be done to alter the pH level prevailing in the medium. The reasons are economics and nitrogen conservation. To change the pH requires the addition of a reagent, which in turn involves a two-fold cost, that of the reagent and that of applying the reagent (N.C.A.R.F. Report, 1964).

e. Water content.--The theoretical optimum moisture content in an aerobic decomposition process is 100% of the total dry weight of solids (Jeris, 1970). The practical moisture content, however, is a function of aeration capacity of the process equipment and of the structural nature of the material being decomposed. From a strictly biological point of view, the ideal arrangement would be to slurry the

refuse and then to vigorously bubble air through the slurry at a rate at which the slurry would be completely aerobic.

The usual practice has been to resort to "dry" handling, i.e., the material is not suspended in water. With this type of handling, in other words, with aerobic decomposition in general, the structural strength of the material to be decomposed determines the upper permissible moisture content. The relation between structure and moisture content stems from the fact that the modern processes is an aerobic process. Oxygen is made available to the bacteria by way of air contained in the interstices at the time the windrow was formed. The maximum permissible moisture contents for various wastes are listed in Table 2.1.

TABLE 2.1.--Maximum Permissible Moisture Contents for Aerobically Decomposing Matter (after Regan and Jeris, 1970)

Type of Waste	Moisture Content Percent Total
Theoretical	100
Straw	75 - 85
Wood (sawdust, small chips)	75 - 90
Paper	55 - 65
"Wet" waste (vegetable trimmings, lawn clippings)	50 - 55
Municipal refuse	55 - 56
Manure (without bedding)	55 - 65

As Table 2.1 indicates, the maximum permissible moisture content for aerobic decomposition of wastes that are rarely "fibrous" (straw, hay, dry leaves, etc.) is within the range of 75 - 85%. On the other hand, wastes consisting mostly of paper or green vegetation (lawn clippings, vegetable trimmings, wet garbage, etc.) have a maximum permissible moisture content within the range of 50% to 60%. If the maximum permissible moisture content for a given waste is excessively low, the problem can be reduced by adding an absorbent waste to the material. Thus, if straw is added to vegetable trimmings, the maximum permissible moisture rises in proportion to the amount of straw added. The addition of an absorbent also is required if the moisture content of the waste in its "raw" state is excessively high, as for example, cannery wastes.

The minimum moisture content at which bacterial activity takes place is from 12 to 15%. Obviously, the closer the moisture content of a decomposing mass approaches these low levels, the slower will be the decomposition process. As a rule of thumb, the moisture content becomes a limiting factor when it drops below 45 or 50% (Miehe, 1907).

f. Oxygen availability (aeration).--Decomposition of solid waste processes are almost universally aerobic and oxygen availability is an important environmental factor. The rate of oxygen uptake is one of the first questions asked when research concerned with aerobic decomposition is undertaken. The earliest reports on oxygen uptake were reported by Schulze (1960) and Popël (1961). Schulze estimated that an air supply equivalent to 18,000 to 22,000 cu.ft. per ton of

volatile matter per day was necessary in his studies to maintain aerobic conditions during peak oxygen demands. Chrometzka (1968) lists oxygen requirements ranging from 9 mm^3/gram/hour for ripe compost to 284 mm^3/gram/hour for "fresh" waste (4 weeks old). He also reported that moisture content is a determinant of the oxygen requirement. For example, the requirement for fresh compost having a 45% moisture content was 263 mm^3/gram/hour; whereas with the moisture at 60%, it was 306 mm^3/gram/hour. Lossin (1971) reports average chemical oxygen demands ranging from almost 900 mg/gram at one day to about 325 mg/gram at 24 days. Regan and Jeris (1970) in a review of cellulose and refuse decomposition compiled a table listing oxygen uptake at various temperatures and moisture contents. The lowest uptake, 1.0 mg O_2/gram of volatile solids per hour, took place when the temperature of the mass was 30°C and the moisture content was 45%. The highest uptake, 13.6 mg/gram volatile matter per hour, occurred when the temperature was 45°C and the moisture content was 56%.

The range of values cited emphasize two points: (1) the difficulty of determining true oxygen requirements, and (2) the desirability of using the chemical oxygen demand (COD) as a measurement of oxygen requirements in terms of rate. These problems stem from the influence exerted by temperature, moisture content, size of bacterial population, and availability of nutrients on oxygen uptake. If one wishes to translate oxygen uptake into amount of aeration required, the problem becomes even more complex, because the aeration equipment and physical nature and arrangement of the material must be taken into consideration.

g. Substrate type.--The nature of the substrate is that of the wastes being processed. This waste, with rare exception, must be organic. In the chemical sense "organic" covers a multitude of materials. In terms of aerobic decomposition (composting), it refers mostly to "organic" as interpreted in the popular sense, e.g., to paper, wood, manures, food preparation wastes, crop wastes, etc. In terms of microbial nutrition, all of these forms are highly complex substances, and thus are not available to a large number of groups of micro-organisms. It is only as the materials are decomposed to more simple forms that the spectrum of potential microbial users broadens. The course of breakdown for the protein content is: Protein → peptide → amino acids → ammonium compounds → bacterial protoplasm and atmospheric nitrogen or ammonia. This breakdown is highly abbreviated and does not take into consideration possible intermediate and side reactions. For example, each step is accompanied by the synthesis of bacterial protoplasm. When an organism decomposes a substrate, some of the nitrogen is transformed into protoplasm. The following simplified scheme includes the complex carbonaceous part of the substrate: carbohydrate → simple sugar → intermediates → CO_2 and bacterial protoplasm.

An important feature of a substrate, as far as aerobic decomposition is concerned, is the availability of nutrients in the substrate to the micro-organisms. Thus, the carbon in raw wastes might just as well not be there as far as the greater part of the indigenous population is concerned. In its existing form, the carbon cannot be

assimilated. If the first members of the microbial succession were missing, nothing would happen. However, such an event rarely happens; and to paraphrase a biblical remark, refuse carries the seeds of its own destruction. The important point is that the simpler the form in which the waste occurs, the wider the array of bacterial species to which it is subject to attack--and hence the more rapid the pace at which aerobic decomposition proceeds. Consequently, vegetable trimmings from a supermarket compost much more rapidly than does straw or sawdust.

4. Factors Influencing Anaerobic Decomposition Rates

a. Micro-organism types.--The micro-organisms in an anaerobic operation are highly specialized bacteria. Aerobic micro-organisms, fungi and protozoa cannot live in the anaerobic environment; and yet periodic isolation of fungi from sludge removed from a digester has caused some people to wonder if fungi are not important (McKinney, 1962). Actually, fungi spores and protozoa cysts are unaffected by the digestion process and can be isolated from digesting sludge by means of aerobic isolation techniques. The spores are merely resting as they pass through the digester on their way to a more suitable environment.

The two groups of bacteria commonly encountered in anaerobic decomposition processes include facultative bacteria and obligate anaerobic bacteria. The acid formers are mostly facultative bacteria with a few anaerobes. The ease in growth of facultative bacteria give

them an edge over anaerobes much in the same way that they have an edge over the aerobes in activated sludge. It is interesting to note that the predominant bacteria in activated sludge and in one phase of anaerobic digestion are one and the same group of bacteria. Various species of pseudomonas, flavobacterium, alcaligenes, escherichia, and aerobacter contribute to acid production.

The methane formers, obligate anaerobes, are a small specialized group of bacteria. These bacteria have been difficult to isolate and study, hence, very little is known about the individual microorganisms. Those bacteria which have been isolated belong to the genera methanobacterium, methanosarcina, and methanococus.

A third group of bacteria which occur in anaerobic digesters include desulfovibrio. Their importance depends upon the sulfate concentration. They are strict anaerobes which utilize sulfates as their hydrogen acceptor with the production of hydrogen sulfide as the reduced end product. In domestic sewage the sulfate reducers are not a significant part of the bacterial population, but in industrial wastes such as those high in calcium sulfate, anaerobic digestion would pose a definite problem.

b. Carbon to nutrient ratio.--The formation of microbial protoplasm, the net result of organic matter degradation, requires a definite quantity of nitrogen and phosphorus as well as trace elements (Waksman, 1953). The nutrient requirements have generally been expressed in terms of a carbon/nitrogen ratio. Domestic sewage contains all the elements required by bacteria. Some industrial wastes,

e.g., pulp and paper mill wastes are deficient in key elements. Nitrogen and phosphorus are the primary nutritional elements missing in industrial wastes. The exact quantity of nitrogen and phosphorus required for a waste can be determined from the quantity of sludge produced per day. The pounds of nitrogen required per day equal 10% of the volatile solids (dry weight basis) produced each day, while phosphorus requirements equal one-fifth of the nitrogen requirements.

Bacteria make use of nitrogen in the form of ammonia, but have the ability to utilize nitrites and nitrates as well as gaseous nitrogen under certain circumstances. Most facultative bacteria of importance in activated sludge have the ability to reduce nitrates to nitrites and through a series of intermediates to ammonia for incorporation into protoplasm. This assimilative reduction of nitrates and nitrites is specific for meeting their protoplasmic needs and can occur in the presence of excess oxygen, but will not occur as long as there is an excess of ammonia.

The use of gaseous nitrogen is limited to the azotobacter, the nonsymbiotic nitrogen-fixing bacteria. In the absence of any nitrogen source and in highly specific carbon sources, it is possible to build up an activated sludge from azotobacter. The azotobacter fix only enough nitrogen from the atmosphere to meet their protoplasmic demands and do not fix excess nitrogen for their neighbors, as is sometimes erroneously thought. The nitrogen which appears in solution comes from lysing of the azotobacter and permits normal bacteria to grow in

solution. Other nutrient elements including potassium, calcium, magnesium, molybdenum, cobalt, and iron are required in trace quantities.

One of the most important aspects of nutritionally deficient wastes is their effect on biological predomination. A partially nitrogen-deficient waste will stimulate fungi over bacteria, since fungi form protoplasm with a lower nitrogen content than bacteria.

The major elements in protoplasm include carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). If protoplasm is to be formed, the substrate must supply each element in the right quantity. While C, H, O, and N are the major elements of protoplasm, other elements required include phosphorous (P), sulfur (S), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn). Lacking these elements, the micro-organisms cannot form protoplasm and carry out metabolic reactions at their optimum rate. Examination of dry protoplasm for bacteria gives the approximate concentrations of the major elements shown in Table 2.2.

c. Toxicity.--There are many materials, both organic and inorganic, which may be toxic or inhibitory to the anaerobic decomposition process. The term "toxic" is relative and the concentration at which a material becomes toxic or inhibitory may vary from a fraction of a mg/l to several thousand mg/l. The general effect which results from the addition of most toxic substances to biological systems is illustrated in Fig. 2.5. At a very low concentration, stimulation of activity is usually achieved. This stimulatory concentration may

TABLE 2.2.--Concentration of Major Elements in a Bacterial Cell (after McKinney, 1962)

Element	Concentration Percent
C	49.0
H	6.0
O	27.0
N	11.0
P	2.5
S	0.7
Na	0.7
K	0.5
Ca	0.7
Mg	0.5
Fe	0.1

range from only a fraction of a mg/l for heavy metal salts to over one hundred mg/l for sodium or calcium salts. As the concentration is increased above the stimulatory concentration, the rate of biological activity begins to decrease. A point is then reached where inhibition is apparent and the rate of biological activity is less than that achieved in the absence of the material. Finally, at some high concentration, the rate of biologcial activity approaches zero.

Micro-organisms usually have the ability to adapt to some extent to inhibitory concentrations of most materials. The extent of adaptation is relative, and in some cases the activity after acclimation may approach that obtained in the absence of the inhibitory material, and in other cases the acclimation may be much less than this.

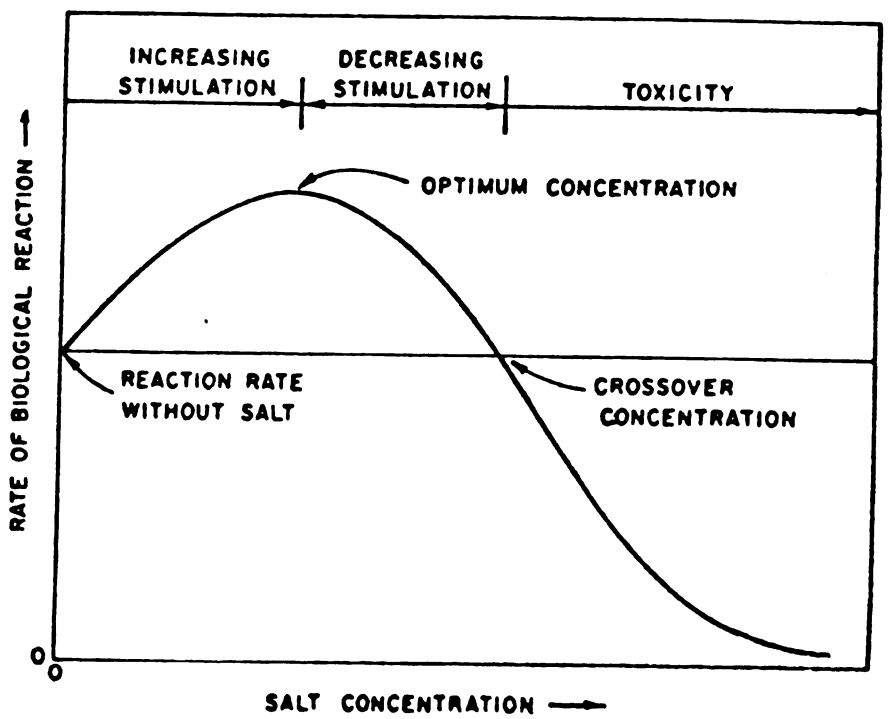


Fig. 2.5.--General effects of salt on biological reactions (after McCarty, 1964).

1. Alkali and alkaline-earth salt toxicity: Industrial wastes usually contain a high concentration of alkali and alkaline earth-metal salts including sodium, potassium, calcium or magnesium. They are frequently the cause of inefficiency in or failure of anaerobic treatments. The concentration of these salts in municipal waste sludge is normally sufficiently low. The concentrations of the cations of salts which may be stimulatory and those which may be inhibitory to anaerobic treatment are listed in Table 2.3.

TABLE 2.3.--Stimulatory and Inhibitory Concentrations of Alkali and Alkaline-Earth Cations (after McCarty, 1964)

	Concentrations in mg/l		
Cation	Stimulatory	Moderately Inhibitory	Strongly Inhibitory
Sodium	100-200	3500-5500	8000
Potassium	200-400	2500-4500	12000
Calcium	100-200	2500-4500	8000
Magnesium	75-150	1000-1500	3000

2. Ammonia toxicity: As a result of the anaerobic decomposition of wastes containing proteins or urea, ammonia is formed. Inhibitory concentrations (1500-3000 mg/l) may be approached (McCarty, 1964).

Ammonia may be present during treatment either in the form of the ammonium ion (NH_4^+) or as dissolved ammonia gas (NH_3). These forms are in equilibrium with each other, the relative concentration of each

depending upon the pH or hydrogen ion concentration as indicated by the following equilibrium equation:

$$NH_4^+ \rightleftarrows NH_3 + H^+$$

When the hydrogen ion concentration is sufficiently high (pH of 7.2 or lower), the equilibrium is shifted to the left so that inhibition is related to the ammonium ion concentration. At higher pH levels, the equilibrium shifts to the right and the ammonia gas concentration may become inhibitory.

The ammonia nitrogen concentrations which may have an adverse effect on anaerobic treatment are listed in Table 2.4.

TABLE 2.4.--Effect of Ammonia Nitrogen on Anaerobic Treatment (after McCarty, 1964)

Ammonia Nitrogen Concentration mg/l	Effect on Anaerobic Treatment
50 - 200	Beneficial
200 - 1000	No adverse effect
1500 - 3000	Inhibitory at high pH
Above 3000	Toxic

3. Sulfide toxicity: In anaerobic treatment sulfides can be introduced with (1) raw wastes and/or (2) direct production by microorganisms through the reduction of sulfates and other sulfur-containing inorganic compounds. Soluble sulfide concentrations ranging from 50 to

100 mg/l can be tolerated in anaerobic decomposition processes with little or no acclimation required. With continuous operation, soluble sulfide concentrations up to 200 mg/l can be tolerated with no significant inhibitory effect on anaerobic treatment (McCarty, 1964). Concentrations above 200 mg/l are toxic.

4. Heavy metal toxicity: Low, but soluble, concentrations of copper, zinc and nickel salts are toxic. These salts are associated with most of the problems of heavy metal toxicity in anaerobic treatment. Concentrations of the more toxic heavy metals (copper, zinc and nickel) which can be tolerated are related to the concentration of sulfides available to combine with the heavy metals to form the very insoluble sulfide salts. Such salts are inert and do not adversely affect the micro-organisms. When the available sulfide concentration for precipitation is low, only small quantities of heavy metals can be tolerated. However, for high sulfide concentrations relatively large amounts of heavy metals can be tolerated with no detrimental effects. In summary, sulfides, by themselves, are quite toxic to anaerobic treatment, as are the heavy metals, however, when combined together, they form insoluble salts which have no detrimental effect.

5. Toxic organic materials: Organic materials which may inhibit the digestion process range from organic solvents to many common materials such as alcohols and long-chain fatty acids. Organic materials which are toxic at high concentration, but which can be anaerobically treated at low concentration, can be adequately handled

by continuous feed to the treatment unit. By continuous feed, these materials are degraded as rapidly as they are added, and their concentrations in the digester can be maintained well below that of the feed itself.

Other toxic organic materials can be treated successfully if they can be precipitated from solution. For example, sodium oleate, a common fatty acid which forms a base for ordinary soap, was found to inhibit anaerobic decomposition in concentrations over 500 mg/l. However, by adding calcium chloride, the insoluble calcium oleate salt is formed, which can be treated successfully even when the concentration in the digester exceeds 2,000 to 3,000 mg/l. Fatty acids are normally present in municipal waste sludges as the insoluble calcium salt and thus do not adversely affect the anaerobic treatment process.

d. Hydrogen ion concentration (pH).--One of the best controls on microbial growth is pH. At low pH the hydrogen-ion concentration causes denaturation of the key enzyme proteins. Most micro-organisms cannot survive below pH 4.0. Only a few sulfur oxidizing bacteria can exist at pH of 1.0. The same is true of the hydroxyl-ion concentration. As the pH rises over 9.5, the hydroxyl ion begins to exert a toxic effect. Few, if any, micro-organisms can survive above pH 11. Control of pH at either a high or low range can be used to prevent decomposition of stored waste matter until desired. PH is the most significant economic control the sanitary micro-biologist has over the growth and death of micro-organisms.

The pH of liquor undergoing anaerobic treatment is related to several different acid-base chemical equilibria. At the near neutral pH of interest for anaerobic treatment (between 6 and 8) the major chemical system controlling pH is the carbon dioxide-bicarbonate system. This system is related to pH or hydrogen ion concentration through the equilibrium equation:

$$[H^+] = K_1 \frac{[H_2CO_3]}{[HCO_3^-]} \qquad (2.3)$$

The carbonic acid concentration (H_2CO_3) depends on the percentage of carbon dioxide in the digester gas, K_1 is the ionization constant for carbonic acid, and the bicarbonate ion concentration (HCO_3^-) forms a part of the total alkinity in the system. The relationship between these factors for anaerobic treatment near 35°C is shown in Fig. 2-6.

e. Temperature.--Biological reactions proceed at a faster rate with higher temperatures, resulting in a more efficient operation. McCarty (1964) and McKinney (1962) report two optimum temperature levels for anaerobic treatment, one in the mesophilic range (29°C to 38°C), and the other in the thermophilic range (49°C to 57°C), although anaerobic decomposition proceeds more rapidly at thermophilic temperatures, the additional energy required to maintain such temperatures may offset the advantages. Most treatment systems are designed to operate in the mesophilic range or lower.

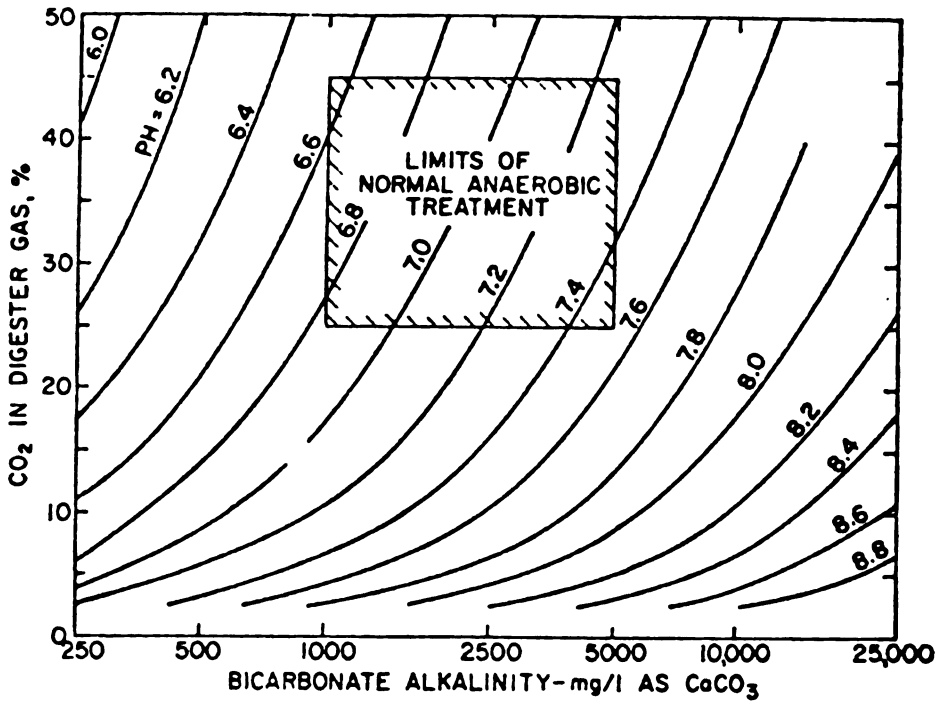


Fig. 2.6.--Relationship between pH and bicarbonate concentration near 35 °C (after McCarty, 1964).

f. Substrate type.--Since anaerobic decomposition processes are employed in the treatment of domestic sewage, it is logical to look at the composition of such wastes. The domestic sewage contains both inorganic and organic compounds. The organic fraction averages approximately 300 mg/l, dry weight, with a range from 100 to 500 mg/l.

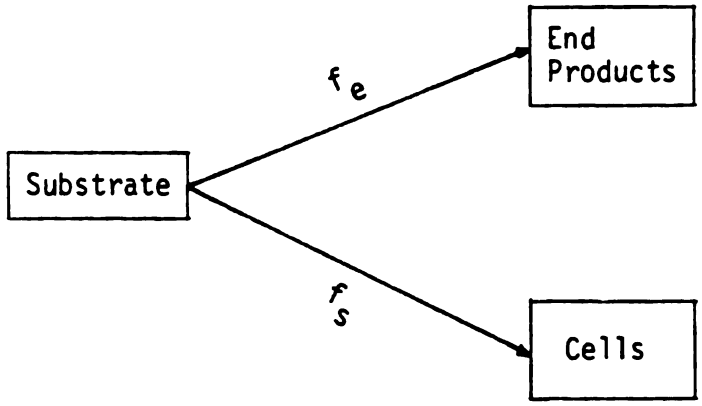
The organic matter in sewage can be divided into three major groups (McKinney, 1962): proteins, carbohydrates, and fats. About 40 to 50% of the 300 mg/l organic solids is protein, 40 to 50% is carbohydrate, and 5 to 10% is fat. The proteins are complexes of amino acids which form the major source of microbial nutrients. The carbohydrates can be divided into two groups: (1) the readily degradable starches and sugars and (2) cellulose. The starches and sugars are easily metabolized by micro-organisms in sewage, while the cellulose compounds are degraded at a much slower rate. The fats are not very soluble and are degraded by micro-organisms at a very slow rate.

5. Cell Yield (Aerobic vs. Anaerobic)

The observed cell yield of heterotrophic microbes growing axenically in chemostat cultures have been explained in terms of endogeneous catabolism of cell substance and substrate oxidation to supply a maintenance energy. As a result of the decomposition processes (aerobic or anaerobic), the organic matter will be transformed into gases, water, and bacterial cells. Therefore, a 100% biologically decomposed material will result in less than 100% weight loss of the

organic matter since part of it will be bacterial cells produced during the decomposition process.

McCarty (1969) outlined a procedure which will estimate the fraction of a decomposing material that will be used in the production of new micro-organism cells. A brief description of McCarty's model follows. The total energy in a substrate equals the sum of energy used in the production of end products and the energy used in the production of new cells;



where f_e = fraction of substrate used for energy, and f_s = fraction of substrate used for synthesis. Therefore, $f_e + f_s = 1$. The energy available in a system can be found using the following equations:

$$\text{Energy available} = f_e \, \Delta G_r K_1$$

where K_1 is the efficiency factor ($K_1 = 0.5$ for anaerobic, $K_1 = 0.6$ for aerobic), and ΔG_r is Gibb's free energy. For a balanced system the energy required for synthesis can be expressed as

$K_1 f_e \Delta G_r = f_s \Delta G_s$. The cell yield is then calculated using the equation:

$$Y = \frac{f_s \nu_c M_c}{\nu_s M_s}$$

where ν_c is the stoichiometric coefficient of cells ($\nu_c = \frac{1}{20}$), ν_s is the stoichiometric coefficient of substrate ($\nu_s = \frac{1}{24}$ for glucose), M_c is the molecular weight of cells (M_c = 113 average), and M_s is the molecular weight of substrate (M_s = 180 for glucose).

a. Aerobic cell yield.--Consider the example where glucose is the organic substrate with an efficiency factor K_1 = 0.6 for both aerobic and anaerobic decomposition. The cell yield is calculated as a percent of the total dry organic weight.

(1) The half reaction for substrate is

$$\frac{1}{24} C_6H_{12}O_6 + \frac{1}{4} H_2O = \frac{1}{4} CO_2 + H^+ + e^-$$

($\Delta G^{\circ\prime}$ = -10.02, after McCarty, 1964).

(2) The half reaction for the product is

$$\frac{1}{4} O_2 + H^+ + e^- = \frac{1}{2} H_2O$$

($\Delta G^{\circ\prime}$ = -18.675 after McCarty, 1964).

By combining the substrate half reaction with that of the product, gives:

$$\frac{1}{24}\ C_6H_{12}O_6 + \frac{1}{4}\ O_2 = \frac{1}{4}\ CO_2 + \frac{1}{4}\ H_2O$$

$\Delta G_r^{\circ'} = -10.020 - 18.675$ and $(\Delta G_r^{\circ'} = -28.695)$.

(3) The half reaction for pyruvate (this is the final product after which no decomposition will take place).

$$\frac{1}{10}\ CH_3COCOO^- + \frac{2}{5}\ H_2O = \frac{1}{5}\ CO_2 + \frac{1}{10}\ HCO_3^- + H^+ + e^-$$

$(\Delta G^{\circ'} = -8.545$ after McCarty, 1964)

Combining the pyruvate half reaction with the substrate half reaction gives

$$\frac{1}{24}\ C_6H_{12}O_6 + \frac{1}{4}\ H_2O = \frac{1}{4}\ CO_2 + H^+ + e^-$$

$$(\Delta G_p^{o'} = -10.020 - (-8.545) = -1.475$$

$$\Delta G_s = \frac{\Delta G_p}{k_1^n} + \Delta G_c + \Delta G_n$$

If $\Delta G_p^{o'} < 0$ implies that $n = -1$

$\Delta G_p^{o'} > o$ implies that $n = 1$ and $\Delta G_c = 7.5$ (constant)

$$\Delta G_s = (-1.475)(0.6) + 7.5 = 6.615$$

$$A = -\frac{\Delta G_s}{K_1\ \Delta G_r} = -\frac{6.615}{(0.6)(-28.695)} = \frac{f_e}{f_s} = 0.384$$

therefore $f_e = 0.384\ f_s$.

But $f_e + f_s = 1$

$$1.384\ f_s = 1 \text{ and } f_s = 0.722$$

(4) Now calculate the cell yield:

$$y = \frac{f_s\ \nu_c\ M_c}{\nu_s\ M_s} = \frac{(0.722)(1/20)(113)}{(1/24)(180)}$$

$$y = 0.5439\ \frac{\text{gm of cells}}{\text{gm of substrate}}$$

b. Anaerobic cell yield.--Unlike aerobic decomposition, anaerobic decomposition could result in the production of methane and volatile acids. The following procedure for cell yield determination takes these differences into account as follows:

(1) The half reaction for substrate--same as aerobic, since the same organic matter is assumed.

(2) The products half reaction is

$$\frac{1}{8}\ CO_2 + H^+ + e^- = \frac{1}{8}\ CH_4 + \frac{1}{4}\ H_2O$$

($\Delta G^{\circ\prime}$ = 5.763 after McCarty, 1964)

By combining the substrate half reaction with the products half reaction gives:

$$\frac{1}{24}\ C_6H_{12}O_6 = \frac{1}{8}\ CO_2 + \frac{1}{8}\ CH_4$$

($\Delta G_r^{\circ\prime}$ = -10.02 + 5.763 = -4.257

(3) The half reaction for pyruvate is the same as in aerobic decomposition. Therefore,

$$(\Delta G_p^{\circ\prime} = -1.475) \text{ and } \Delta G_s = 6.615$$

Substitution of $\frac{f_e}{f_s} = 2.59$ in $f_e + f_s = 1$ gives $f_s = 0.2786$

(4) The anaerobic cell yield is

$$y = \frac{(0.2786)(1/20)(113)}{(1/24)(180)} = 0.2099 \frac{\text{gm cells}}{\text{gm substrate}}$$

6. Organic Content Determination in Soils

The organic material in soil is generally combustible carbonaceous matter, whereas the mineral constituent--whether part of the plant growth or extraneous matter--is non-combustible and ash forming. In practice two distinctly different methods are used in the determination of organic contents. A brief description of these methods follows.

a. Ignition test.--The ignition test (ASTM D586-63) determines the ash content of paper and paper products. This ash is defined as the residue after complete combustion of the paper at 925 ± 25°C (1967 ± 45°F). Paper may include various residues from chemicals used in its manufacture, metallic matter from machinery and mineral matter in the pulp from which the paper was made.

The test equipment includes a platinum crucible with lid, an analytical balance having a sensitivity of 0.1 mg, and an

electric muffle furnace, controlled to maintain a temperature of 925 ± 25°C. The material is sampled in accordance with ASTM method D 585. The test sample consists of small pieces of paper so selected as to be representative of the test unit. The sample weight must be of a size sufficient to yield an ash weight of not less than 10 mg and preferably over 20 mg.

After carefully cleaning the empty crucible, it is loaded with the sample which is ignited in a muffle furnace at 925 ± 25°C. After ignition, the sample is cooled slightly and then placed in a desicator. When cooled to room temperature, weigh the crucible. The ash content is then determined from the equation

$$X_m = \frac{\text{weight of ash}}{\text{dry weight of sample}} \times 100$$

The organic content X_F is then $X_F = 1 - X_m$.

In the firing process, more than organic carbon is burned off. This approximate method of determining the organic content can err from 5 to 15%.

b. Chemical oxygen demand (COD).--The chemical oxygen demand determination is a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. Determination of the COD for both filtrate samples and whole sludge samples is made possible by using a modified standard procedure (Eastman, 1977). In the modified method, volumes of both sample and $K_2Cr_2O_7$ are adjusted so that the minimum sample

volume is one milliliter so that 50 to 90% of the $K_2Cr_2O_7$ will be consumed. The procedure is summarized in the following paragraphs.

1. Principle: Most types of organic matter are destroyed in a boiling mixture of chromic and sulfuric acids. The sample is refluxed with known amounts of potassium dichromate and sulfuric acid and the excess dichromate is titrated with ferrous ammonium sulfate. The amount of oxidizable organic matter, measured as oxygen equivalent, is proportional to the potassium dichromate consumed.

2. Interference and inadequacies: Straight-chain aliphatic compounds, aromatic hydrocarbons and pryidine are not oxidized to any appreciable extent. Assuming that no nitrite is present, this method is limited in its application to organic soils by the small sample which can be oxidized. For a nonuniform soil, difficulty in obtaining a representative sample could result in a great variability of results.

3. Apparatus: Reflux apparatus, consisting of 250 ml Erlenmeyer flasks with ground-glass 24/40 neck and 300 mm Jacket Liebig., West, or equivalent condensers, with 24/40 ground-glass joint, and a hot plate having sufficient power to produce at least 1.4 W/M^2 (9 W/in^2) of heating surface, to insure adequate boiling of the contents of the refluxing flask.

4. Reagents:

(1) Potassium Dichromate Solution, 1.000N: dissolve 49.036 gm $K_2Cr_2O_7$, primary standard grade, previously dried

at 103°C for 2 hours, in distilled water and dilute to 1000 ml.

(2) Sulfuric Acid Reagent: concentrated H_2SO_4 containing 22 gm silver sulfate, Ag_2SO_4, per 4 kg bottle (1 to 2 days required for dissolution).

(3) Ferrous Ammonium Sulfate Titrant 0.4 N: dissolve 156 gm $Fe(NH_4)_2(SO_4)_2 \cdot 6\ H_2O$ in distilled water. Add 20 ml concentrated H_2SO_4, cool, and dilute to 1,000 ml. Standardize this solution daily against the standard $K_2Cr_2O_7$.

(4) Ferroin Indicator Solution: this indicator solution may be purchased already prepared.

(5) Mercuric Sulfate, $HgSO_4$, crystals.

5. Test procedure (Eastman, 1977): Accurately pipet 1 to 5 ml of sample into a 250 ml refluxing flask, then add approximately 1 gm of $HgSO_4$ and 3 glass beads. Accurately add 1 to 10 ml of 1.000 N $K_2Cr_2O_7$ and also prepare one blank containing the same amount of $K_2Cr_2O_7$. Add sufficient distilled water to bring the total liquid volume to 20 ml. Connect the flask to the reflux condenser, and add 20 ml H_2SO_4, containing $AgSO_4$, through the top of the condenser through which cooling water is already flowing. After adding acid mix the sample thoroughly. Reflux two hours or until all material hanging from the condenser has fallen back and no more accumulates. Reflux the blank in the same manner. Cool the flask by adding distilled water to about 100 ml. Titrate with 0.4 N $Fe(NH_4)_2(SO_4)_2$ standardized against the same volume of $K_2Cr_2O_7$ as used for the samples.

This method was tested (Eastman, 1977) for recovery of the theoretical oxygen demand of short chain volatile acids. The results showed essentially complete recovery.

C. Consolidation Parameters of Organic Soils

Certain fundamental physical properties (e.g., consolidation parameters, shear strength, etc.) of organic soils characterize, to some extent, the quality of that soil, as an engineering material. In this section the void ratio, compression index, coefficient of compressibility, and the coefficient of consolidation are reviewed.

1. Void Ratio

The void ratio gives an indication of the compressibility of a material; the higher the initial void ratio the greater the potential compressibility. The natural void ratio of fibrous peat, for example, is usually very high. A value as high as 25 has been reported (Hanrahan, 1954). The natural void ratio of amorphous peats, is generally quite low, with values as low as 2 having been reported (Hillis and Brawner, 1961). The usual range is from 5 to 15. The relationship between void ratio and water content is shown in Fig. 2.7.

2. Compression Index

The compression index is defined as the slope of the void ratio (e) vs. the log of applied stress (σ'_c) curve. This parameter is very useful in characterizing the consolidation behavior of mineral soils. Use of the compression index in settlement

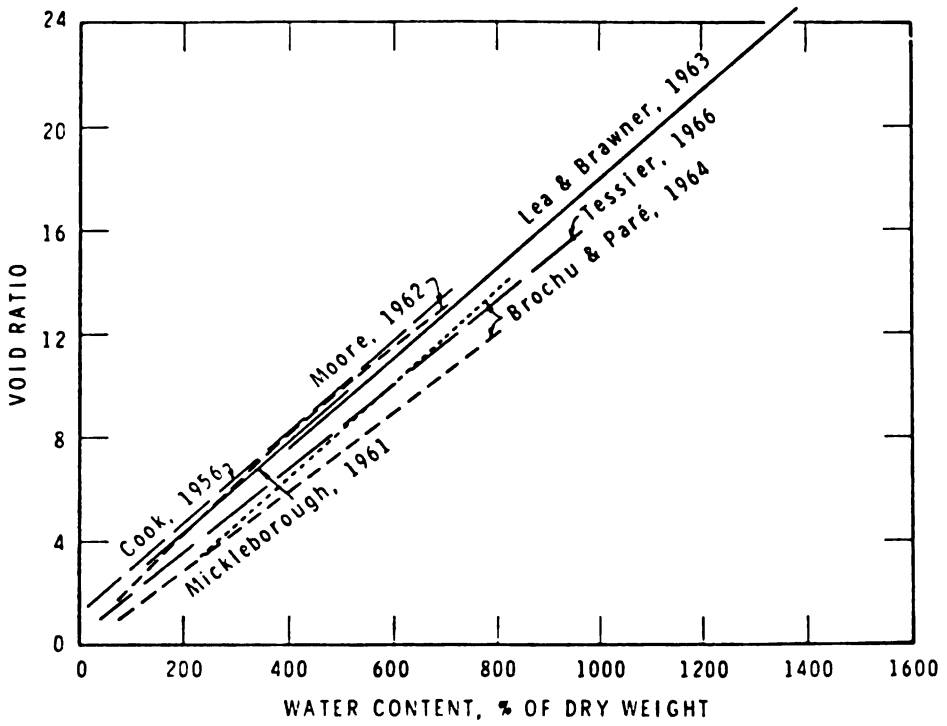


Fig. 2.7.--Void ratio vs. water content (after MacFarlane, 1969).

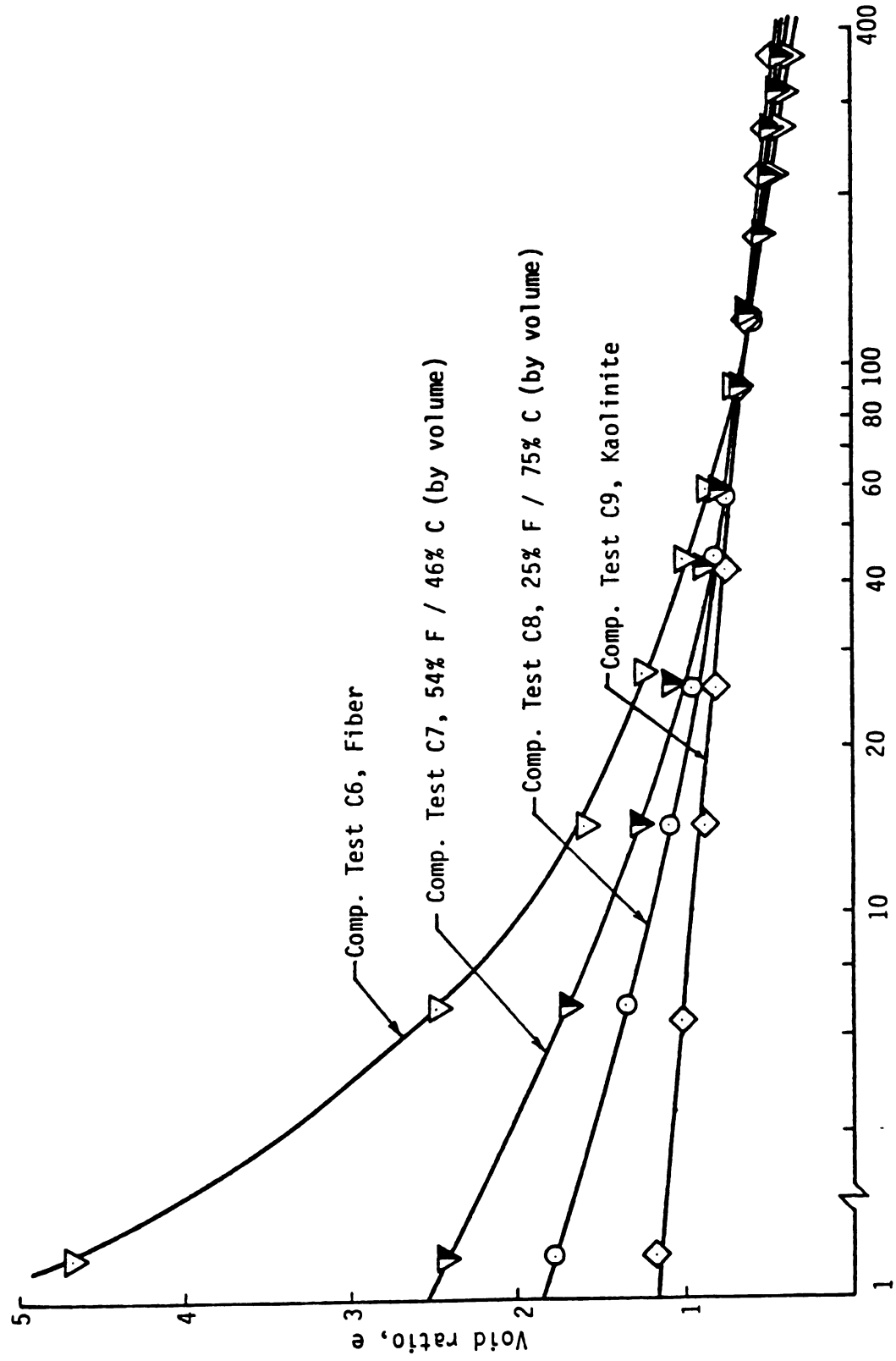


Figure 2.8--Effective normal stress vs. Void ratio curves for the Kaolinite/fiber samples on a semi-logarithm scale (after Khattak, 1978).

calculations for mineral soils is justified since there is a linear relationship between e and log σ_c', hence a unique value can be obtained by which the stress increment is directly related to the change in void ratio. Unfortunately, this is not the case with organic soils. Khattak (1978) has reported different e versus log σ_c' for different organic contents (Fig. 2.8). Two obvious conclusions can be readily drawn:

1. For a given stress increment, there are an infinite number of compression indices. This stems from the nonlinear e versus log σ_c' curves.
2. The compression index of an organic soil depends on both the stress level and the organic content.

The implication is that errors will be introduced if the compression index is used in settlement calculations of organic soils.

3. Coefficient of Compressibility

This parameter represents the slope of void ratio versus effective normal stress. A nonlinear relationship is shown to exist between the coefficient of compressibility and void ratio in Fig. 2.9. Different curves are reported by different researchers. These curves illustrate the problems engineers face in dealing with organic soils. Despite the availability of a large amount of information on the coefficient of compressibility and other parameters, it is evident that many gaps in the knowledge still exist and that much of the available data is contradictory and/or confusing. Better correlations between reported data and actual field behavior are still needed.

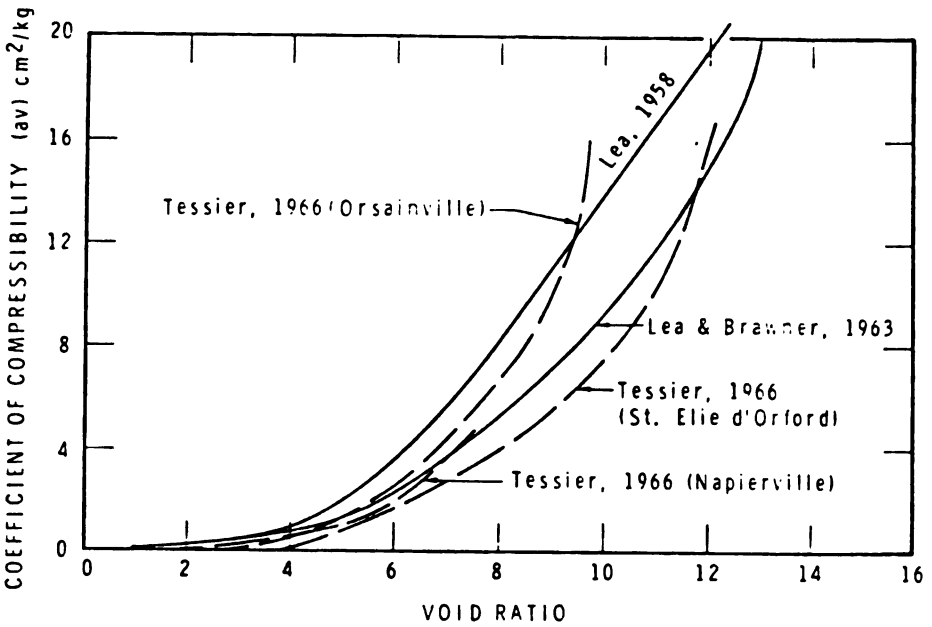


Fig. 2.9--Coefficient of compressibility (a_v) vs. void ratio for organic soils (after MacFarlane, 1969).

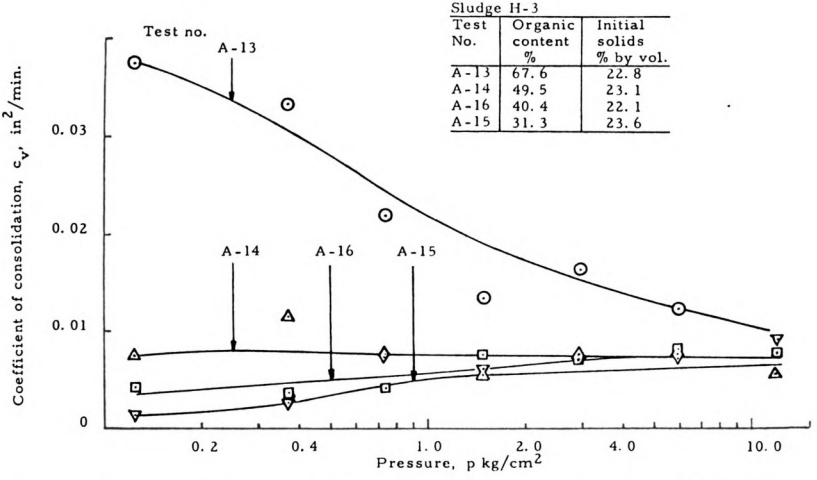


Figure 2.10.--Coefficient of consolidation versus logarithm of pressure for Sludge H-3 with different organic contents (after Paloorthekkathil, 1972).

4. Coefficient of Consolidation

The coefficient of consolidation, c_v, for a given soil is a measure of the rate at which that soil consolidates. Paloorthekkathil (1972) investigated this parameter by testing sludges with different organic contents. Some of his results are summarized in Fig. 2.10. Examination of these curves leads to the conclusion that for organic soils with an organic content of 40% or less, the coefficient of consolidation will increase with increasing pressure. However, for sludges with an organic content greater than 40%, the coefficient of consolidation decreased as the pressures increased. Hence, c_v appears to be some function of both organic content and pressure level.

D. Strength and Elastic Parameters of Organic Soils

A rational analysis of geotechnical field problems involving organic soils requires a knowledge of their stress-strain behavior and shear strength characteristics. Highway construction problems are concerned with the surface mat of decomposable material and the stability of road embankments and dykes. These problems require data on strength and their variation under loading throughout the full depth of organic soil. Large deformations must occur for organic soils to develop their full resistance to applied loads. This is a result of their high compressibility. Another unusual property of organic soils is their range of natural water contents, as low as 50% but as high as 2000% based on the dry weight of solids, compared to inorganic soils. This means that the natural water

content to organic soils may range from 10 to 100 times greater (MacFarlane, 1969).

Organic soils can show a large anisotropy. Permeability is much higher in the horizontal direction than in the vertical direction. This, coupled with instability of the solid phase due to decomposition, makes organic soils that much more difficult to deal with in design problems. For these reasons early research concerning the engineering characteristics of organic soils was directed to the problem of whether they could be assessed in terms of the current concepts of soil mechanics developed primarily for inorganic soils.

Qualitatively, the shear strength of organic soils varies inversely with its water content and directly with its ash content and degree of compression deformation (Wyld, 1956). Efforts were directed to the establishment of relations between shear strength and water content (Hanrahan, 1954). The preferable approach, however, is that of assessing the shear strength in terms of an angle of internal friction (Andersland and Laza, 1971).

1. Shear Strength Parameter

Early tests for the shear strength of organic soils suggested that its strength was largely cohesive (Hanrahan, 1954). More recent research has shown conclusively that it is essentially a frictional material and that it behaves closely in accordance with the principles of effective stress (Adams, 1961). Using consolidated-undrained triaxial tests on peat, observed friction angles, ϕ', as

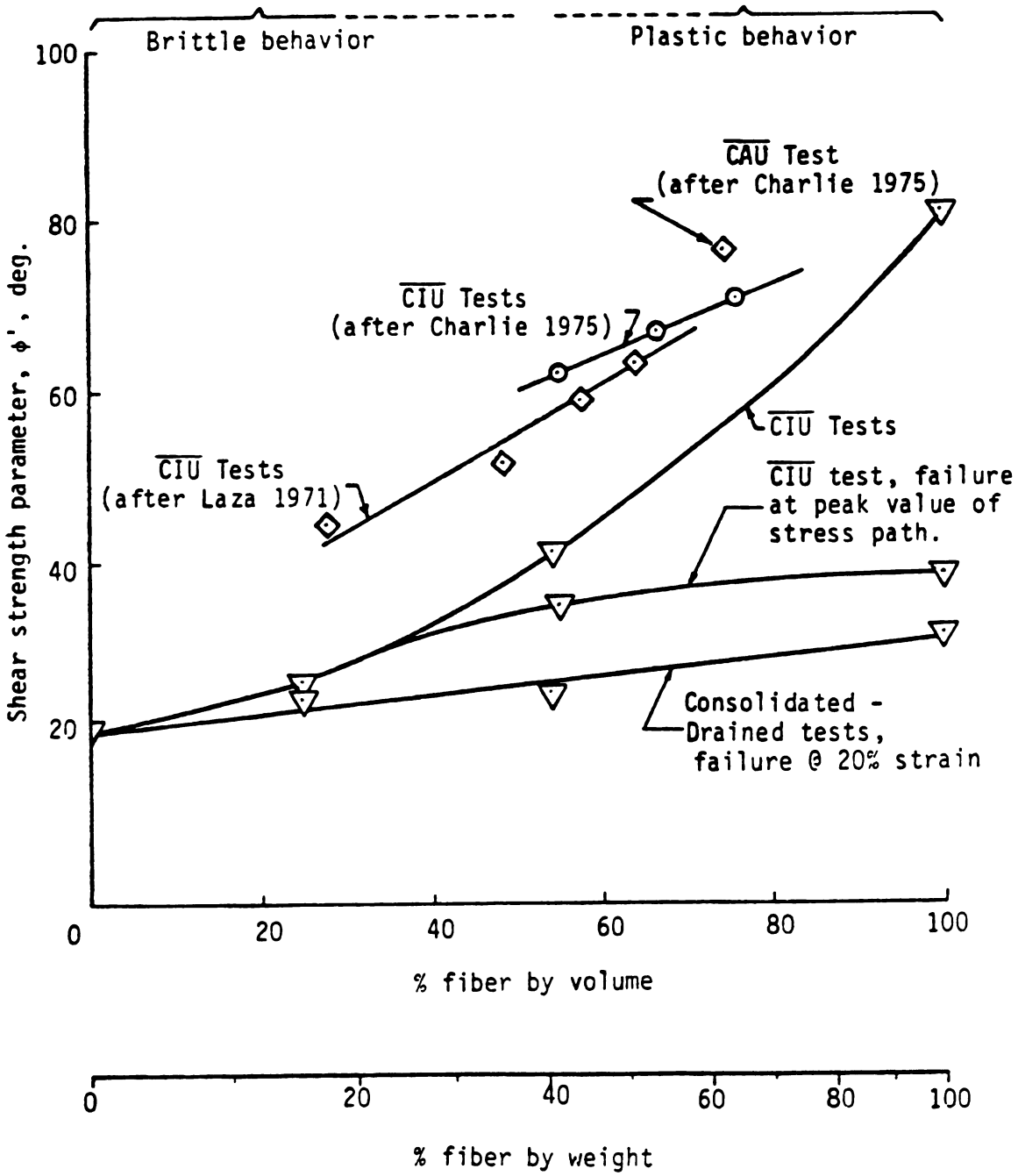


Figure 2.11.--Fiber (organic) content vs. shear strength parameter ϕ', consolidated undrained and consolidated drained triaxial tests (after Khattak, 1978).

large as 50 degrees were reported (Adams, 1961). For fresh papermill sludges Laza (1971) reported that organic content had a direct influence on the frictional characteristics of these soils. More recent work (Andersland and Khattak, 1979) shows that the shear strength ϕ' is dependent not only on organic content, but also on test conditions (Fig. 2.11).

For many practical problems, shear strength of the organic soil is not necessarily the governing factor in design. Design is more likely to be governed by the deformation characterisitcs of highly organic soil. In such cases, values for ϕ' or ϕ_u can usually be estimated with sufficient accuracy (MacFarlane, 1969). For cases where higher precision is desirable, either in situ or laboratory tests are necessary.

2. Cohesion

There does not appear to be any reported method of assessing what provides the greatest contribution to strength and other mechanical properties of organic soils. Although organic soils are frictional in character, they do exhibit some cohesion. Andersland and Laza (1971) used consolidated-undrained triaxial tests with pore pressure measurements on an integrated pulp and papermill sludge. Cohesion values, ($\bar{c}$), on an effective stress basis, ranged from zero to 0.3 kg/cm^2. Cohesion c, based on total stress, is dependent on organic (fiber) content and the overburden pressure. For uniform normally consolidated papermill sludge deposits the ratio of undrained

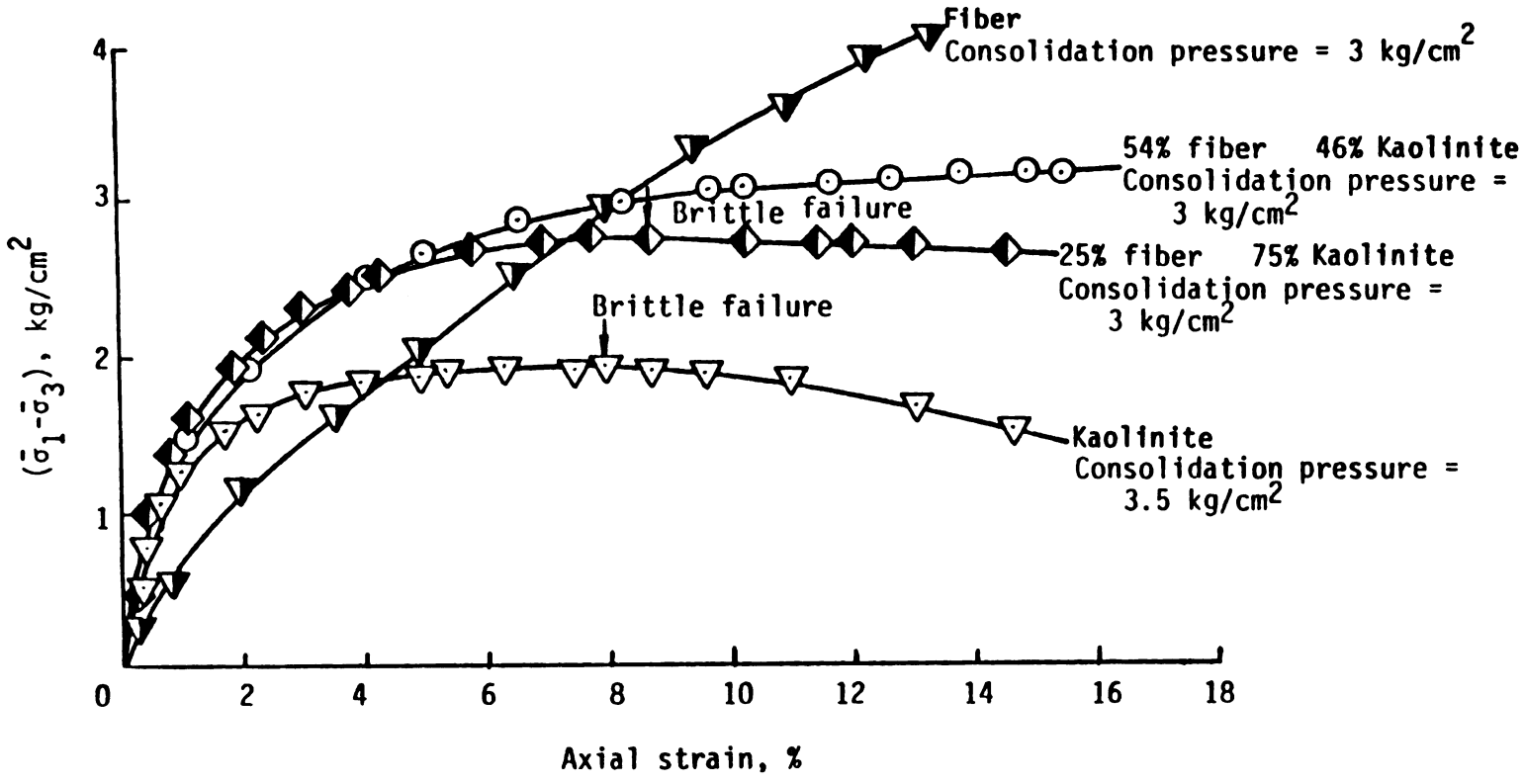


Figure 2.12.--Stress-strain curves for samples with varying Kaolinite/fiber compositions showing the change in failure mechanisms for undrained conditions (after Khattak, 1978).

shear strength c_u to the effective overburden stress p is found to be constant (Mazzola, 1969).

3. Modulus of Elasticity

When organic soils are stressed, whether in tension or compression, very large deformations result, compared to those for most inorganic soils. Very little fundamental research has been carried out on the stress-strain relationship, and how it is affected by factors such as organic content, type of organic matter, etc. Schroeder and Wilson (1962) studied an amorphous-granular peat and concluded that it was a pseudo-plastic material. Tressider (1958) stated that, when loads on peat are small or rapidly applied, both elastic and viscous properties are readily noticeable. Hanrahan (1964) states that a proportionality exists between the vane shear strength and the modulus of elasticity. Andersland and Khattak (1979) reported stress-strain curves for various organic contents and consolidation pressures (Fig. 2.12). These curves have no clear elastic range, although at strains below 2%, an elastic behavior may be assumed with no loss of accuracy. The nonlinearity encountered with samples containing 0 to 40% organic matter has been substantially reduced in the case of samples containing 100% cellulose fibers. It is also clear that no definite peak exists for the highly organic stress-strain curves. This points out the difficulty in determining where failure has taken place. Strain hardening is certainly occurring, since larger strains result in higher strengths as shown in Fig. 2.12.

CHAPTER III

MATERIALS STUDIED AND SAMPLE PREPARATION

A. Materials Studied

One of the objectives of this research project was to formulate a suitable procedure by which the fiber/clay samples could be prepared for test purposes. The samples were to simulate a range of organic soils encountered in the field. This would, then, serve as a guide in illustrating the feasibility of application and practicality of test results.

Soils of organic origin are generally formed in situ, either by the growth and decay of plants or by accumulation of fragments of inorganic skeletons. Inclusive in this category are top soil, muskeg, marl, muck, and peat. Waste-papermill sludges, which in addition to the inorganic mineral content contain cellulose fiber in the form of fines, may be expected to exhibit soil properties similar to an organic soil (Mazzola, 1969; Andersland and Laza, 1971).

Since cellulose, in different forms constitutes the main source of most organic matter in soil, it is logical to select it as the source of organic matter in the samples prepared for this study. Due to their large surface areas clay minerals have a definite affinity for adsorbing organic matter on these surfaces. Therefore, clay was chosen as the source of the inorganic mineral fraction for the laboratory prepared samples.

1. Cellulose

Cellulose forms the structural fiber of many plants, and is characterized by its abundance, diversity of source and range of use. High grade cellulose can be produced from wood through sulfite and kraft pulping processes, followed by bleaching, leaving in solution lignin, hemi-celluloses, pentosans, wood sugars and other extraneous substances. Like starch, cellulose is composed of a chain of glucosidic units numbering in the thousands. The beta linkage connecting these units can by hydrolyzed by the digestive system of certain animals, which have specific enzyme-producing bacteria in their digestive tracts capable of this fermentation reaction.

Different types of cellulose are encountered in organic soil deposits, especially in landfills of paper mill sludges. The importance attached to the type and source of organic matter (cellulose, or otherwise) stems from their different degradability potentials.

Lomova (1964) observed that decomposition rates of cellulosic substances, is dependent on the fiber source and concentration in sludges. Table 3.1 shows the biochemical oxygen demand for different types of fiber in different concentrations.

B. softwood kraft was used as the source of organic matter in our samples. It is a logical choice because it gives reasonably close values of BOD to the mean.

TABLE 3.1.--The Effect of Cellulose Fiber Concentration and Source on Biochemical Oxygen Demand (after Carpenter & Owens, 1968)

Fiber Source	(5-Day BOD, mg/liter/gm of fiber)				
Fiber Conc. mg/L	1000	2000	3000	4000	5000
B. Softwood K.	78	45	26	19	17
B. Hardwood K.	24	17	23	17	11
Unbleached K.	141	75	65	43	34
Groundwood	62	65	47	39	32
Bleached Sulfite	14	54	24	24	20
Alpha Cellulose	57	27	10	21	10
Mean	63	47	32	27	20

2. Clay

In soil science, many of the clays are classified as colloidal with the boundary between colloidal and noncolloidal sized materials arbitrarily set at two microns, 0.002 mm (Capper, 1953). Clay is a collection of microscopic and submicroscopic particles derived from the chemcial decomposition of feldspar and other alumina-silica rocks. This weathering process may occur in several ways (Huber, 1955), for example: (1) by decomposition of silicate minerals, (2) by solution of a carbonate rock containing insoluble clay impurities deposited as an insoluable residue, and (3) by disintegration, accompanied by some solution of shales.

The clay minerals can be generally classified into the following groups:

I. Two-Layer Clays

A. Equidimensional
Kaolinite Group

B. Elongated
Halloysite Group

II. Three-Layer Clays

A. Expanding Lattice

1. Equidimensional

a. Montmorillonite group, full expansion
b. Vermiculite, limited expansion

2. Elongated
Montmorillonite Group

B. Nonexpanding Lattice
Illite Group

III. Four-Layer Clays

Chlorite Group

IV. Chain-Structure Groups
Attapuligate

A single particle of clay consists of a multitude of sheets arranged one upon another with flat surfaces carrying residual negative charges. The electrical charges are developed at the edges of the crystal due to broken bonds or isomorphous substitution. The charges contribute to the clay's ability to hold ions.

The form of clay used in the paper industry is kaolin, a china clay, composed essentially of a clay material low in iron and generally white in color. The main constituent of kaolin is the mineral kaolinite with nacrite, dickite, and a halloysite comprising the lesser

quantities. The kaolinite unit is composed of a single silica tetrahedra sheet and a single alumina octahedral sheet.

The presence of clay in a soil is significant to its physical, chemical, and biological behavior. The cohesiveness of clay and the ability of some clays to shrink and swell accounts for their physical role. The chemical significance lies in the cation exchange capacity of clay. The biological effects are indirect. The resistance to degradation of microbial substrates bound to clay has been studied by many researchers; Alexander (1965) observed that clay minerals have the capacity to absorb or adsorb a variety of polysaccharides of which cellulose is one type. This sorptive ability is due mostly to the large surface area. Allison (1949) noted that clays exerted a depressing effect on the rate of mineralization of several substances, thereby stabilizing them. After 12 months of decomposition with such substances, 23% of the carbon was retained in a sand culture, whereas sand containing 30% kaolin retained 31% of the carbon. This inhibitory effect may occur not only by binding the substrate, but also by retaining enzymes catalyzing the decomposition (Lynch, 1956).

Kaolinite clay was chosen as the inorganic mineral source in making our organic sample. Chemically and biologically kaolinite is one of the least active among the colloidal groups. This property was the main reason behind this choice. Other factors include its application to the paper manufacturing process, and its nonexpanding or contracting nature.

3. Nutrients

The normal growth of micro-organisms in excess nutrients results in cells of a definite chemical composition. Examination of many different bacteria grown under many different environmental conditions indicates that bacteria are 80% water and 20% dry matter. The dry matter is 90% organic and 10% inorganic. The organic fraction consists of 53% carbon, 29% oxygen, 12% nitrogen, and 6% hydrogen. The organic fraction gives an approximate empirical formulation of $C_5H_7O_2N$ (McKinney, 1962). The inorganic fraction averages 50% P_2O_5, 6% K_2O, 11% Na_2O, 8% MgO, 9% Ca, 15% SO_3, and 1% Fe_2O_3. The bacteria must derive all the basic elements for protoplasm from the liquid environment. If the environment is deficient in one or two elements, the bacteria will develop only in proportion to the chemical deficiency.

The percentages of the different nutrients, organic and inorganic in the aerobic and anaerobic decomposition processes for our research program was determined using the average formula weight for bacteria shown in Table 2.2. Although the types of micro-organisms participating in the aerobic decomposition process are different from that in the anaerobic, bacteria are generally present in both processes.

a. Source of carbon (c).--Pulp fiber, used as the main source of organic matter in the organic samples, supplied the carbon for the purpose of studying the effects of decomposition on the various engineering properties of the decomposed soil. The chemical formula of

cellulose is given in the literature as $C_6H_{10}O_5$. The molecular weight of cellulose is then found to be 6 x 12 + 10 x 1 + 5 x 16 = 162 gms. Therefore, the percent carbon in cellulose can be found as the fraction of one molecular weight of cellulose

$$\text{Percent carbon (C)} = \frac{6 \times 12}{162} = 0.4444$$

or cellulose has 44.44% carbon.

b. Source of nitrogen (N).--Two different sources of nitrogen were used in supplying the required quantities of this nutrient. Ammonium sulfate was used as the main source of nitrogen in one set of samples. The same procedure was followed in the determination of percent nitrogen (N) in ammonium sulfate $[(NH_4)_2\ SO_4]$, thus

$$\text{Percent nitrogen (N)} = \frac{28.016}{132.14}\ (100) = 21.20\%$$

Ammonium chloride ($NH_4\ Cl$), used in preparing a second batch of samples, provided nitrogen equal to $\frac{14\ (100)}{53.46} = 26.19\%$.

A summary of all nutrients used in sample make-up are given in Table 3.2. Note that sodium (Na) was supplied during the buffering process through the addition of sodium bicarbonate.

B. Sample Preparation

The constituents of the model organic soil samples included cellulose, kaolinite, and nutrients. Water was added so that the anaerobic samples were saturated and the aerobic samples would contain a water content close to 184%. Hence, the aerobic samples were not necessarily saturated.

TABLE 3.2.--Nutrients Found in Bacterial Protoplasm and Their Percentages in Different Compounds

Nutrient	Nutrient Source	Molecular Weight	Percent Nutrient
Phosphorous (P)	K_2HPO_4	173.18	17.89
Magnesium (Mg)	$MgSO_4$	120.39	20.20
Calcium (CA)	$CaCl_2$	110.99	63.89
Potassium (K)	K_2HPO_4	173.18	45.16
Iron (Fe)	$FeCl_3$	162.22	34.43

1. Fiber Separation, Drying, and Mixing

Soft wood kraft cellulose was obtained by soaking pulp board about 5 to 15 cm^2 in water for 24 hours followed by separating the fibers into a fluffy mass using a food blender. After placing the material (cellulose) in trays, the fibers were dried using an air blowing dryer. The air drying temperatures, about 50°C, was chosen so that the cellulose retained its fluffy appearance with no weight loss. The time required for complete drying was approximately 3 days. The dry material was once again separated using the food blender until the mass became a loose collection of cellulose fibers.

Dry kaolinite was then added in quantities needed to give the desired organic content. Using the food blender, increments of cellulose were added to the clay until the desired proportions were obtained. Although this procedure was time consuming, it was justified because very uniform soil mixtures were obtained.

2. Nutrient Proportions

Using the average formula for bacteria, $C_5H_7O_5N$ (McKinney, 1962) as a guide of micro-organism nutritional requirements, the exact compound amounts required for the sample make up were selected. Average values for the different nutrients found in bacterial protoplasm are given in Table 2.2. Note that the major component is carbon followed by nitrogen and then phosphorous.

Although the carbon to nitrogen ratio has been widely used and studied, no other parameters are available for describing the nutrients which are critical for metabolism of micro-organisms, hence the continuation of the decomposition process. After consultation with committe members, two new parameters were suggested to bridge the gap. The phosphorous to nitrogen ratio (P/N), and all other remaining nutrient (Mg, Fe, K, Ca, and Na) to nitrogen ratios were selected. The choice of nitrogen as the base by which all other nutrients were determined was convenient since they then conformed nicely with the established carbon to nitrogen ratio (C/N). Determination of the respective ratios agree with Table 2.2. These ratios included C/N = 4.45, P/N = 0.23 $\simeq$ 1/5, and (Mg, Fe, K, Ca, and Na)/N = 0.06 $\simeq$ 1/16.

These ratios must be satisfied in order to meet the bacteria nutritional requirements and hence achieve complete degradation of the cellulose. However, complete transformation of cellulose and nutrients into bacterial cells is only an idealization and can be done only in theory. This cannot occur in practice because

1. Part of the carbon will escape as carbon dioxide (CO_2) or methane (CH_4),

2. The efficiency of any system is less than 100%, and

3. The expected cell yield of a decomposed organic matter is considerably less than 50% regardless of the decomposition process.

A more reasonable approach would be to base our calculation on the expected cell yield discussed in Section II.B.5 and Table 2.2 assuming a cell yield of 0.20 (gm cell/gm substrate)will increase the C/N ratio by a factor of $\frac{100}{20} = 5$. Hence, a more logical value for the C/N ratio would be 4.5 x 5 = 22.50. Note that once the C/N ratio is fixed, other ratios must remain constant with respect to nitrogen. This provides a balanced diet for bacterial metabolism.

3. Seeding Material

Microbial species that can survive in unusual environments have been developed for the decomposition of a variety of naturally occurring and synthetic materials. Unfortunately, the microenvironments may be either high or low in nutrient content, each with its characteristic species composition.

Using several seed organism sources, Carpenter and Owen (1968) studied the possibility of selective growth of micro-organisms to be used for the rapid decomposition of cellulose. Their findings were that sewage, sawdust, and compost drainage served most effectively in the degradation of cellulose. The effectiveness of such microbial seeds was attributed in part to their probable history of prior exposure to cellulosic materials.

In the test program municipal sludge was used as the micro-organism source for the anaerobic decomposition process. Garden soil was used as the source of micro-organisms for the aerobic decomposition. The amount of seeding material used was about 1% of the total dry sample weight. This amount was shown to be adequate by Waksman (1953). The purpose for adding seeding material was to accelerate the decomposition process, by adding micro-organisms responsible for decomposition.

4. Buffering

Decomposition produces volatile acids, which, if allowed to go unchecked, may depress the pH below 6. This unbalance must be corrected to prevent the elimination of methane producing bacteria (which favor pH of 6.2-6.8). For the anaerobic process to be a success, a balance must be maintained so that the methane producing bacteria will use up just enough volatile acids, produced by acid-forming bacteria, to give a tolerable pH for both micro-organisms.

For the anaerobic samples, including stages I, II, and III, the pH was controlled by adding sodium bicarbonate. Sodium bicarbonate, although seldom used in practice, is one of the most effective materials for pH control in anaerobic treatment methods (McCarty, 1964). This material has significant advantages over other materials. It is relatively inexpensive. It does not react with carbon dioxide to create a vacuum, and there is little danger that it will raise the pH to undesirable levels. It is quite soluble and can be dissolved prior to addition to the decomposing samples. This material can be added

to give an alkalinity of 5,000 to 6,000 mg/l without producing any adverse or toxic effects.

5. Aerobic Samples

Organic contents were selected so as to encompass the full range of organic contents encountered in the field. Samples with organic contents of 30, 60, and 80% by weight, were used in the aerobic decomposition process. For convenience, pulp fiber was used as the organic matter source.

Four carbon to nitrogen ratios were fixed: 5, 10, 30, and 50 for each of the organic contents. Appendix A-0 includes a block diagram describing these samples. The water content, 65% of the total sample weight, was selected on the basis of data given in Table 2.2. In terms of the dry weight of solids, the water content (X_w) is

$$X_w = \frac{w}{1 - w} \times 100 = \frac{0.65}{1 - 0.65} \times 100 = 186\%$$

The aerobic samples were tested for initial conditions (Stage I), and final conditions after 2 months of decomposition (Stage II). Tests performed included organic content, vane shear strength at selected consolidation pressures, consolidation behavior, and percent decomposition. Consolidation pressures ranged from 5.8 gm/cm^2 to 46.5 gm/cm^2. This pressure range provided the desired data and were within the load limits of the consolidation apparatus.

Ammonium sulfate was used as the nitrogen source. Although sulfate is toxic to anaerobes in the anaerobic decomposition process,

it is not in the aerobic process. Hence, ammonium chloride could have worked just as well. Prepared samples were placed in three liter beakers. All aerobic samples were then stored in a 100% humidity environment so as to minimize evaporation. Temperature was maintained in the mesophilic range (30-40°C) because it represented an averaged value which the micro-organisms could tolerate and metabolize at a near optimum rate.

Sample size used in each beaker was determined using Fig. 3.1. This graph was developed experimentally using different combinations of clay and cellulose. An equation, derived on the basis of data given in Fig. 3.1, permitted computation of the required clay content for a given organic content and volume.

$$W_c = [285.6\ X_{FO}^2 - 563.5\ X_{FO} + 286.2]\ V_T \qquad (3.1)$$

where W_c is the clay weight in grams, X_{FO} is the desired initial organic content in percent by weight, and V_T is the total required volume in liters. This equation is valid for organic contents in the range of 30 to 80%.

To illustrate preparation of an aerobic sample consider the following example. Calculate the amount of clay to be added to pulp fiber to form one liter of material having an initial organic content of 30%. Substitute $X_{FO} = 0.30$, and $V_T = 1.0$ into equation 3.1 and compute $W_c = 142.85$ grams. Calculate the weight of cellulose required as $\frac{0.30 \times 142.85}{1 - 0.30} = 61.23$ grams. The total weight $W_T = 142.85 + 61.23 = 204$ grams. Using a water content of 0.65

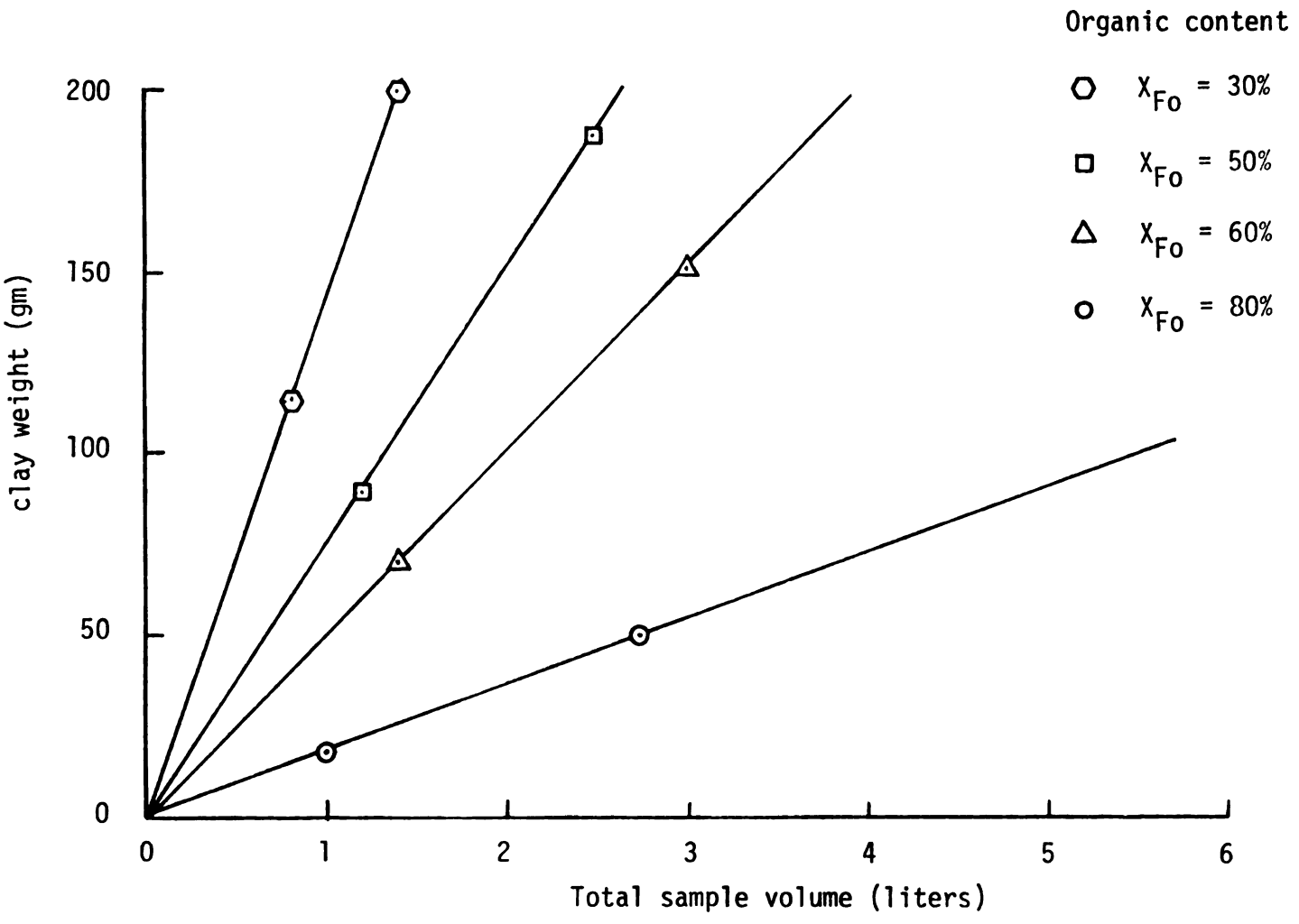


Figure 3.1.--Clay weight versus sample volume for different organic contents.

(based on total weight), the amount of water required is determined as

$\frac{204 \times 0.65}{1 - 0.65}$ = 379 grams.

The nutrients required for a given carbon to nitrogen ratio were determined using the following procedure.

1. Fix the organic content, X_{FO},
2. Fix the phosphrous/nitrogen ratio,
3. Fix (Mg,Fe,K, Ca, and Na)/N ratios
4. For given C/N, determine the weight of carbon in cellulose by multiplying (W_{FO}) by 0.444 (carbon in one molecular wt. of cellulose is 44.44%),
5. From step (2) determine the required nitrogen by dividing the amount of carbon by the carbon to nitrogen ratio,
6. The amount of phospherous can then be determined by dividing the nitrogen obtained in step (5) by the phospherous to nitrogen ratio chosen in step (2),
7. The amounts of Mg, Fe, K, Ca, and Na can be determined following the procedure used in step (6), and
8. Finally, the choice of compound used as the nutrient source for the different nutritional elements added to a sample will determine the amounts of these compounds.

A summary of the calculations for different organic contents and carbon/nitrogen ratios is given in Table A.1.

6. Anaerobic Samples

A procedure similar to that used for aerobic samples was employed in determining the amounts of clay, cellulose, and nutrients required to make a sample with predetermined characteristics. The main difference was the amount of water needed for sample saturation.

Samples with organic contents of 30, 60, and 80% by weight were prepared and placed under a consolidation pressure of 3 gm/cm^2. Their respective volumes were measured under saturated conditions and water contents were then calculated. The results are shown in Fig. 3.2 where water content ($X_w = \frac{\text{weight of water}}{\text{weight of solids}}$) is plotted against organic fiber content (X_{FO}). The amount of water required for complete saturation can be obtained from the organic content.

A summary of all calculations made for the different anaerobic samples are given in Table A.1. All samples were tested for initial conditions (Stage I) and final conditions after two months of decomposition (Stage II). Consolidation, vane shear strength, organic content, percent decomposition, and pH tests were subsequently performed. A detailed discussion of the results follow in later chapters.

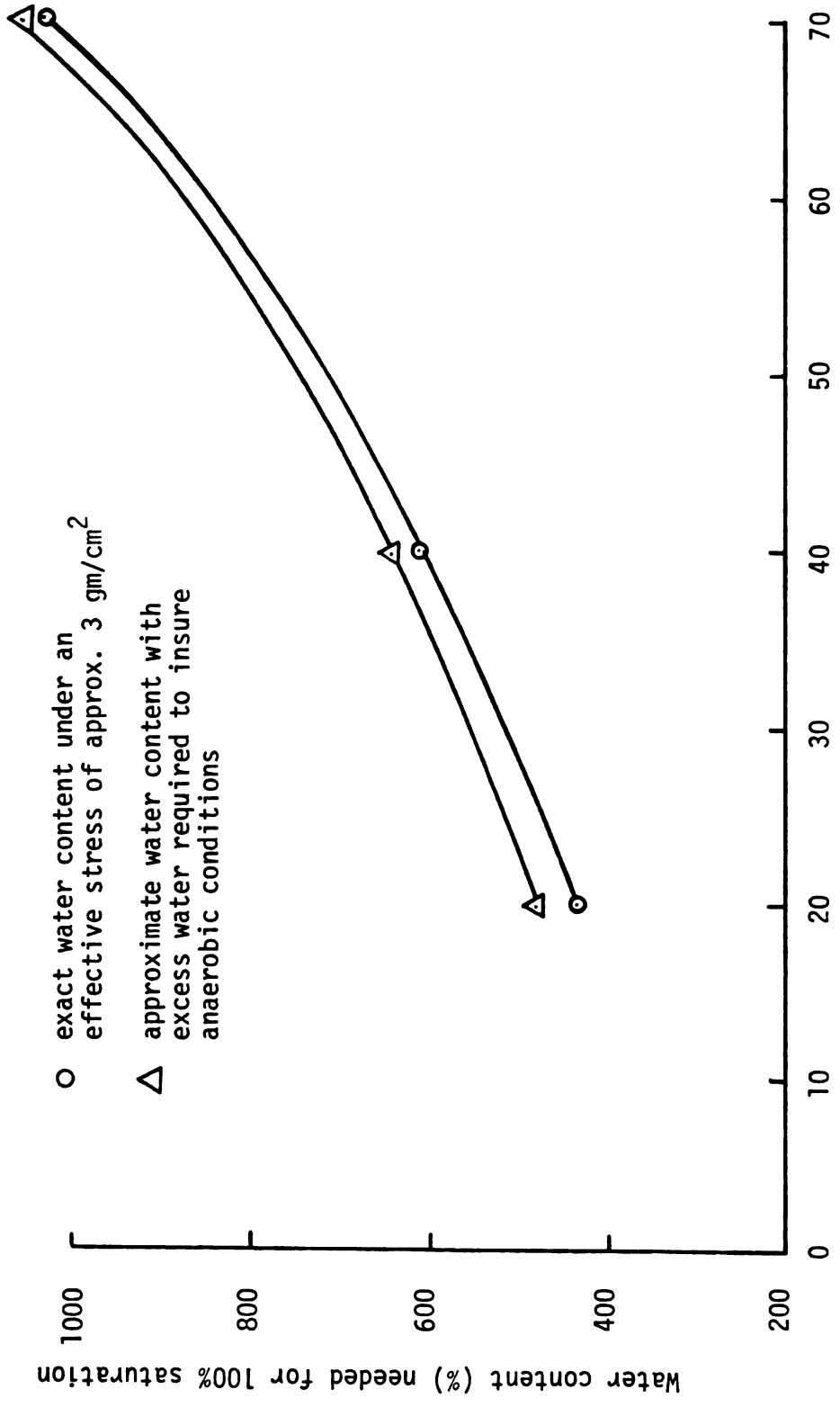


Figure 3.2.--Water content versus organic content.

CHAPTER IV

EXPERIMENTAL EQUIPMENT AND PROCEDURES

A. Organic Content Determination

A modified ash analysis procedure was developed and used in the test program. The method includes solution of linear equations in the determination of organic content. A brief description of the analysis follows with a more extensive discussion in Chapter V.

Curves relating percent weight reduction of cellulose and clay with temperature for different durations of burning were developed. Since organic samples used in the test program contained cellulose and kaolinite, the following definitions are given:

$$W_{CO} + W_{FO} = W_{TO} \tag{4-1}$$

where W_{CO} is the initial weight of kaolinite, W_{FO} is the initial weight of organic matter, W_{TO} is the total solids weight before combustion.

$$\text{Let } C_1(T,D)\ W_{CO} + C_2(T,D)\ W_{FO} = W_{T1} \tag{4-2}$$

where $C_1(T,D)$ is a kaolinite weight factor which is dependent on temperature and duration, $C_2(T,D)$ is an organic weight factor which is dependent on temperature and duration, and W_{T1} is the total sample weight after combustion at temperature (T), and duration (D).

Now define the fraction organic matter and fraction kaolinite as follows:

$$X_{FO} = \frac{W_{FO}}{W_{TO}} \tag{4-3}$$

$$X_{CO} = \frac{W_{CO}}{W_{TO}} \tag{4-4}$$

Next solve equations (4-1) and (4-2) for W_{FO} and W_{CO} and substitute into equations (4-3) and (4-4). The organic and kaolinite contents are determined, respectively, by

$$X_{FO} = \frac{C_1\ (T,D) - (W_{T1}/W_{TO})}{C_1\ (T,D) - C_2\ (T,D)} \tag{4-5}$$

$$X_{CO} = 1 - X_{FO} \tag{4-6}$$

For convenience select a temperature and duration of burning such that $C_2\ (T,D) = 0$. One such combination, corresponds to T = 900°C with D = 1.25 hours giving $C_1\ (900, 1.25) = 0.855$ and $C_2\ (900, 1.25) = 0$. These values are listed in Appendix F. Substituting values for C_1 and C_2 into Equations (4-5) and (4-6) gives:

$$X_{FO} = 1 - 1.168\ \frac{W_{T1}}{W_{TO}} \tag{4.7}$$

$$X_{CO} = 1.168\ \frac{W_{T1}}{W_{TO}} = 1 - X_{FO} \tag{4-8}$$

Equations (4-7) and (4-8) were used for determination of organic contents in the remainder of the study.

The test procedure was simple. A representative soil sample containing organic fiber and kaolinite was dried at a temperature T = 100°C for 24 hours. From this sample 3 to 10 grams were taken for an ash analysis. Using a platinum crucible, this sample was burned at a temperature of 900°C for 1.25 hours. Using equations (4-7) and (4-8), the organic content was computed.

B. Percent Decomposition

In Chapter II the term decomposition was defined as the degradation of organic matter by micro-organisms with time. It is important to note that the decomposition process is a random one, hence non-homogeneous. When a procedure is developed to determine the percent decomposition which a given mass has experienced, the value will reflect an average degree of decomposition rather than an absolute value.

Since both aerobic and anaerobic decomposition processes result in substantial weight losses in the organic matter undergoing decomposition it is logical to take these weight losses as an indicator for the degree of decomposition and define the percent decomposition (X_{DI}) at time interval I as

$$X_{DI} = \frac{W_{FO} - W_{FI}}{W_{FO}} \qquad (4\text{-}9)$$

where W_{FI} = weight of the organic matter at interval I (decomposed weight).

Now define the following quantities:

$$X_{FO} = \frac{W_{FO}}{W_{TO}} = \frac{W_{FO}}{W_{CO} + W_{FO}} \tag{4-10}$$

$$\text{and } X_{FI} = \frac{W_{FI}}{W_{CO} + W_{FI}} \tag{4-11}$$

where X_{FI} = organic content at time interval I. Using equation (4-10) gives

$$X_{FO}\, W_{CO} + X_{FO}\, W_{FO} = W_{FO} \tag{4-12}$$

Solving equation (4-10) for W_{FO} gives

$$W_{FO} = \frac{X_{FO}\, W_{CO}}{1 - X_{FO}} \tag{4-13}$$

Solving equation (4-11) for (W_{FI}) gives:

$$W_{FI} = \frac{X_{FI}\, W_{CO}}{1 - X_{FI}} \tag{4-14}$$

Substituting euqations (4-13) and (4-14) into equation (4-9) gives

$$X_{DI} = \frac{\dfrac{X_{FO}\, W_{CO}}{1 - X_{FO}} - \dfrac{X_{FI}\, W_{CO}}{1 - X_{FI}}}{\dfrac{X_{FO}\, W_{CO}}{1 - X_{FO}}}$$

and $$X_{DI} = 1 - \frac{X_{FI}\,(1 - X_{FO})}{X_{FO}\,(1 - X_{FI})} = \frac{X_{FO} - X_{FI}}{X_{FO}\,(1 - X_{FI})}$$

$$= \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}} \qquad (4\text{-}15)$$

From the initial organic content (X_{FO}) and the decomposed organic content at time interval I, (X_{FI}) the percent decomposition can be calculated using equation (4-15).

C. Specific Gravity

Organic soils generally consist of two components, organic matter and mineral solids. The specific gravity for these soils will be some function of the specific gravities of the organic fraction and the inorganic portion. MacFarlane (1969) suggested that the specific gravity of organic soils is a linear combination of the individual specific gravities, organic and inorganic fractions. Examination of this function shows that it can err by 18% in extreme cases (MacFarlane, 1969). This variable was important for this research, consequently errors of such magnitude were not acceptable. The following derivation introduces a new function which has been used as the basis for estimating the specific gravity for the model organic soils.
The specific gravity of the clay G_{SC} is

$$G_{SC} = \frac{W_{SC}}{V_{SC}\gamma_W} \qquad (4\text{-}16)$$

where w_{SC} = weight of mineral, V_{SC} = volume of mineral with weight of W_{SC}, and γ_w = unit of weight of water. The specific gravity of the organic matter G_{SF} is

$$G_{SF} = \frac{W_{SF}}{V_{SF}\gamma_w} \tag{4-17}$$

where W_{SF} = weight of organic matter, and V_{SF} = volume of organic matter. The specific gravity of the organic soil G_S is

$$G_S = \frac{W_S}{V_S\gamma_w} \tag{4-18}$$

where W_S = weight of organic soil, and V_S = volume of organic soil. For the organic soil

$$V_S = V_{Sc} + V_{SF} \tag{4-19}$$

From equations (4-16), (4-17), and (4-18) note that

$$V_{SC} = \frac{W_{SC}}{G_{SC}\gamma_w} \tag{4-20}$$

$$V_{SF} = \frac{W_{SF}}{G_{SF}\gamma_w} \tag{4-21}$$

and $$V_S = \frac{W_S}{G_S\gamma_w} \tag{4-22}$$

Substituting equations (4-20), (4-21), and (4-22) into equation (4-19) gives

$$\frac{W_S}{G_S\gamma_W} = \frac{W_{SC}}{G_{SC}\gamma_W} + \frac{W_{SF}}{G_{SF}\gamma_W} \tag{4-23}$$

Multiplying equation (4-23) by γ_W and dividing by W_S gives:

$$\left(\frac{W_{SC}}{W_S}\right)\frac{1}{G_{SC}} + \left(\frac{W_{SF}}{W_S}\right)\frac{1}{G_{SF}} = \frac{1}{G_S}$$

or $$\frac{X_{CI}}{G_{SC}} + \frac{X_{FI}}{G_{SF}} = \frac{1}{G_S}$$

and $$G_{SI} = \frac{1}{\frac{X_{CI}}{G_{SC}} + \frac{X_{FI}}{G_{SF}}} \tag{4-23}$$

Equation (4-23) gives the specific gravity for an organic soil as a function of organic and mineral content and their respective fractions by weight. For this study, note that G_{SC} = 2.70 for kaolinite and G_{SF} = 1.54 for cellulose. Since clay and cellulose were used in preparing samples, these values have been used in determining the specific gravity of the organic soil materials. Using numerical values for G_{SC} and G_{SF} in equation 4-23 gives

$$G_{SI} = \frac{1}{\frac{X_{CI}}{2.70} + \frac{X_{FI}}{1.54}} = \frac{1}{0.37\ X_{CI} + 0.65\ X_{FI}} \tag{4-24}$$

Knowing the clay and fiber fractions, X_{CI} and X_{FI}, the specific gravity of organic soils may be computed, using equation 4-24. In Chapter V a comparison is made between MacFarlane's equation for determining the specific gravity of organic soils and equation 4-24.

D. Consolidation

Consolidation is the dissipation of excess porewater pressure with time, or the gradual decrease of water content at a constant load. After initial compression, this process generally proceeds in two stages, primary and secondary. Primary compression is believed due to the drainage of water from the pores accompanied by a reduction in pore size. Secondary compression proceeds after excess pore water pressure becomes hydrostatic. The exact nature of secondary compression is not fully understood, but it is believed to be related to creep.

Conventional soil mechanics consolidation theory for inorganic soils involves setting up an equation from which the excess pore water pressure may be computed at any point and time in a stratum of consolidating soil. The basic assumptions made in applying the conventional consolidation theory include the following: (1) homogeneous soil, (2) complete saturation, (3) negligible compressibility of solid matter, (4) the validity of Darcy's law, and (5) constant properties during each stage of consolidation.

In applying the conventional theory of consolidation to organic soils, two major deviations from the above assumptions are

noted, namely the properties will change as consolidation progresses and the soil may not be completely saturated. These two major differences are believed to account for the significant difference in consolidation behavior between organic and mineral soils (MacFarlane, 1969).

The conventional consolidation theory for mineral soils was used with some modifications in the analysis of test results. Time rate of settlement included the application of Taylor's (1948) method (dial reading vs. $\sqrt{\text{time}}$) for the determination of the coefficient of consolidation. The study has included the coefficient of compressibility (a_v), compression index (C_c), coefficient of permeability (k), coefficient of secondary compression (C_α), water content (X_w), and void ratio. These parameters were carefully observed as decomposition progressed. Therefore, a brief description of test procedure and the consolidation parameter determinations are given.

1. Test Procedure

The consolidation equipment consisted of a soil container (beaker) of approximately 3 liters in volume, a circular lid with a porous stone having an area of 172 cm^2, and a dial gauge accurate to 0.001 inch placed at the center of the lid. Organic samples were initially consolidated due to weight of the lid, which produced a stress of 5.8 gm/cm^2. Excess water which drained to the lid was removed by a vaccuum, after which the sample was permitted to consolidate for 60 minutes. When primary consolidation continued

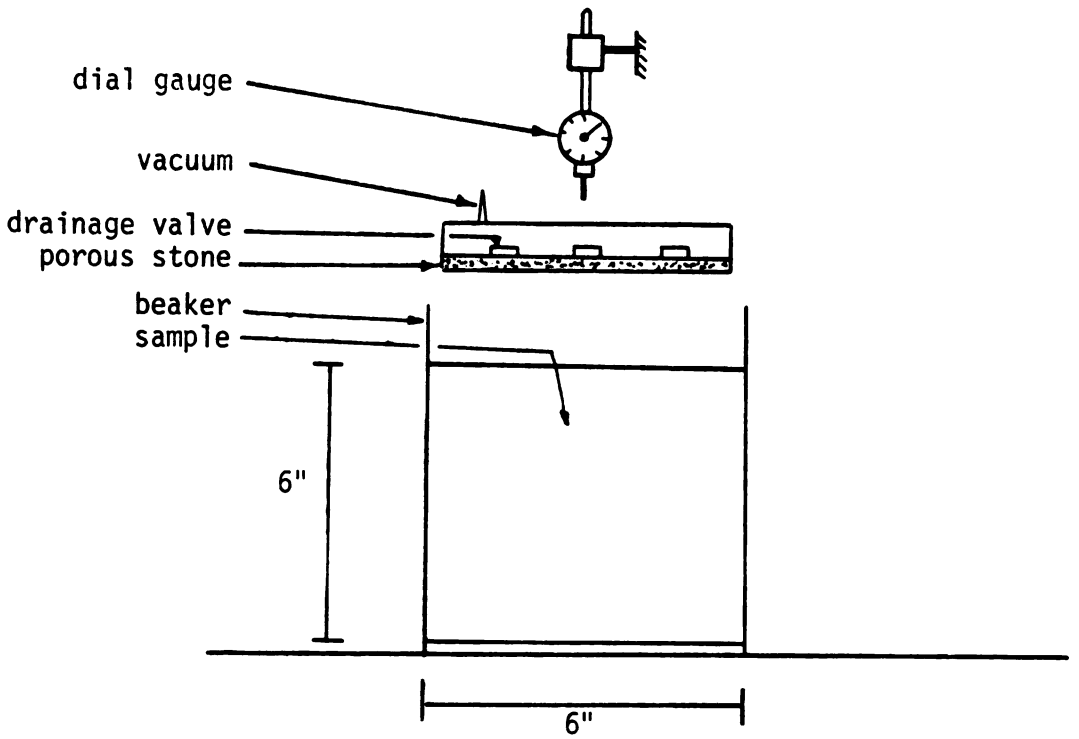


Figure 4.1.--Consolidation apparatus.

beyond 60 minutes, then t_{100} was taken as the determining factor for the duration of a given load increment. Stress increments were applied in the following sequence:

(1)	0 - 5.8 gm/cm^2	(No dial reading)
(2)	5.8 - 11.6 gm/cm^2	(Dial reading vs. time)
(3)	11.6 - 23.3 gm/cm^2	(Dial reading vs. time)
(4)	23.3 - 34.9 gm/cm^2	(Dial reading vs. time)
(5)	34.9 - 46.5 gm/cm^2	(Dial reading vs. time)

A diagram of the test apparatus is shown in Figure 4.1.

2. Coefficient of Consolidation

This parameter was determined from a dial reading versus square root of time plot. A typical plot is shown in Fig. 4-2. The procedure includes an extension of the straight-line portion back to t = 0, giving a corrected zero reading (D_o). Through (D_o) a straight line was drawn with an inverse slope 1.15 times the tangent line, giving d_{90} at the intersection with the laboratory curve. The parameter c_v was computed as follows:

$$c_v = \frac{0.848\ H^2_{avg}}{t_{90}} \tag{4-25}$$

where H_{avg}, the average height of consolidating sample, is

$$H_{avg} = H_{initial} - \left(\frac{D_{100} - D_o}{2}\right) \tag{4-26}$$

and $$D_{100} = \frac{D_{90} - D_o}{0.9} + D_o = \frac{D_{90} - 0.1\ D_o}{0.9} \tag{4-27}$$

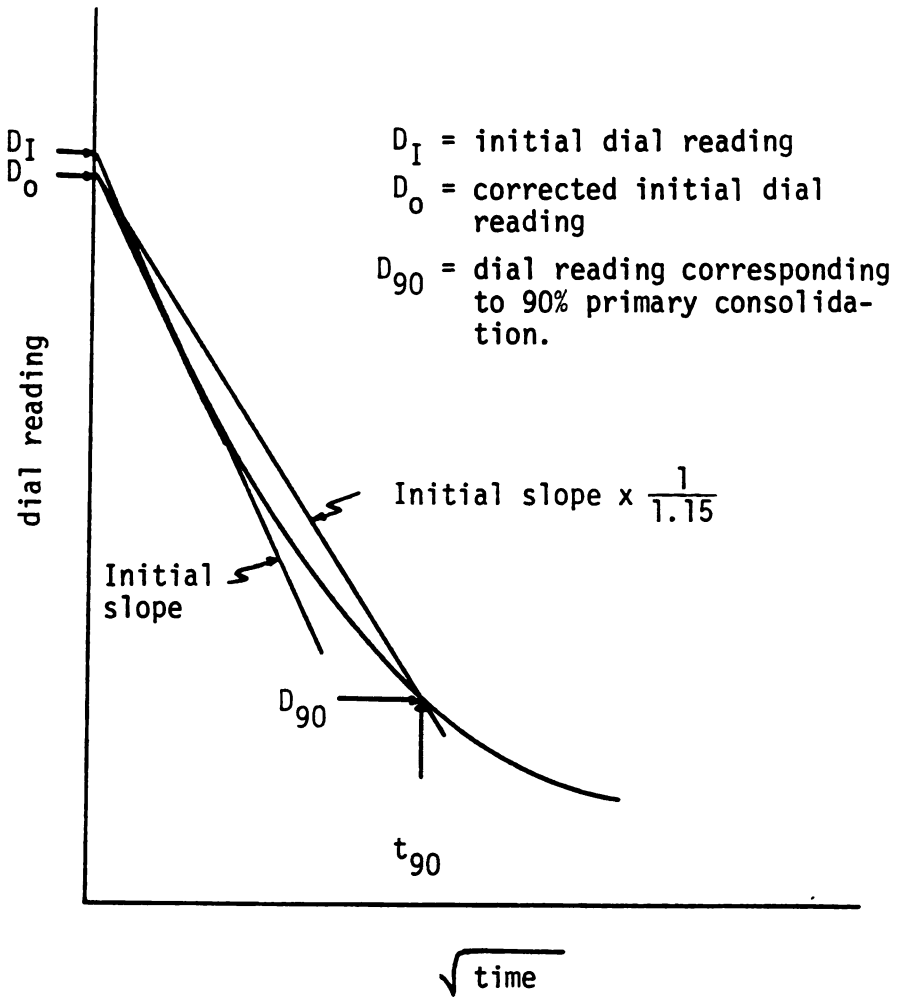


Figure 4.2.--A schematic diagram of dial reading versus square root of time.

3. Void Ratio

The void ratio was determined for initial conditions as the ratio of voids volume to the solids volume ($e = \frac{V_v}{V_s}$). For a decomposing sample, a modified procedure must be developed so that the volume change due to decomposition and ash content tests are taken into account. The equations which follow show a derivation of a modified approach for this void ratio determination.

$$e = \frac{H_f - H_{SI}}{H_{SI}} = \frac{H_f}{H_{SI}} - 1 \qquad (4\text{-}28)$$

where $H_{SI} = W_{SI}/(A\, G_{SI}\gamma_W)$, $W_{SI} = W_{FI} + W_{CI}$, and

$$W_{CI} = (W_{TI} - W_{loss})\, X_{CO} \qquad (4\text{-}29)$$

$$W_{FI} = [(W_{T1} - W_{loss})X_{FO}](1 - X_{DI}) \qquad (4\text{-}30)$$

Initial organic matter weight

Fraction of organic matter remaining after decomposition

Where W_{CI} = weight of clay at interval I

W_{SI} = weight of solids at interval I

H_{SI} = Height of solids at interval I

W_{T1} = Total weight of nutrient free sample

W_{loss} = ash weight loss = Wl

A = Area of sample

H_f = Final height of sample for a given consolidation pressure .

4. Compression Index (C_c)

From the void ratios corresponding to the different effective consolidation pressures, a plot of void ratio versus consolidation pressure was made. The slope of this curve gives the compression index (C_c), which follows, from the definition of (C_c), thus

$$C_c = \frac{\Delta e}{\Delta \log \sigma'_c} \tag{4-31}$$

5. Coefficient of Compressibility (a_v)

By definition $a_v = - \frac{de}{d\sigma'_c}$. Using this equation, a relationship between C_c and a_v can be developed as follows:

$$a_v = - \frac{de}{d\sigma'_c}$$

and $$C_c = \frac{e_o - e}{\log \frac{\sigma'_c}{\sigma'_o}}$$

or $$e = e_o - C_c \log \frac{\sigma'_c}{\sigma'_o}$$

Then

$$a_v = \frac{-d \left(e_o - C_c \log \frac{\sigma'_c}{\sigma'_o}\right)}{d\sigma'_c}$$

$$a_v = \frac{d}{d\sigma'_c} \left(e_o - C_c \log \sigma'_c + C_c \log \sigma'_o\right)$$

$$a_v = - \frac{d}{dp} \left(e_o - C_c \frac{\ln \sigma'_c}{2.3} + C_c \frac{\ln \sigma'_o}{2.3}\right)$$

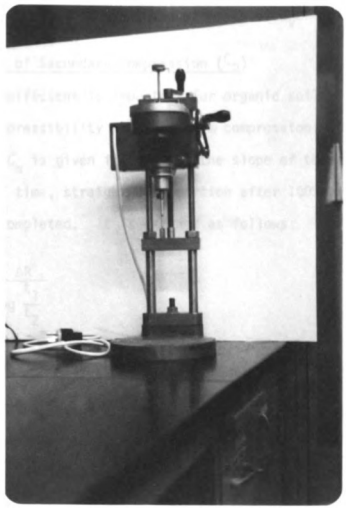


Figure 4.3.--Miniature vane shear appartus.

$$a_v = \frac{C_c}{2.3\sigma'_c} \tag{4-32}$$

Equation (4-34) was used in the determination of a_v.

6. Coefficient of Secondary Compression (C_α)

This coefficient is important for organic soils, because of their large compressibility and long term compression. The usual definition for C_α is given in terms of the slope of the dial reading versus $\log_{10}$ of time, straight line portion after 100% primary consolidation is completed. It is defined as follows:

$$C_\alpha = \frac{\Delta R}{\log \frac{t_1}{t_2}} \tag{4-33}$$

where ΔR = change in dial reading. A plot of dial reading versus log t is shown in Fig. 4.4.

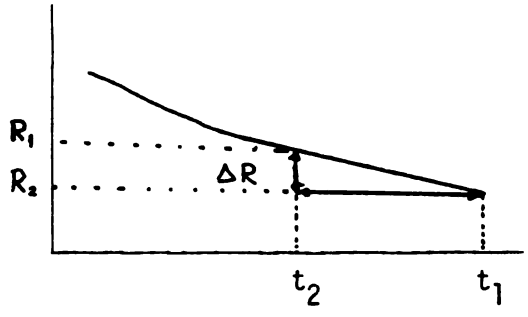


Fig. 4.4.--A schematic diagram of dial reading versus logarithm of time.

Note that settlement due to secondary compression can be calculated as follows:

$$\Delta H_{secondary} = C_{\alpha} \log \frac{t_1}{t_2} \qquad (4\text{-}34)$$

7. Permeability (k)

In the derivation of Terzaghi's equation for the rate of settlement, the coefficient of consolidation was defined by the expression

$$C_v = \frac{k\ (1 + e)}{a_v \gamma_w}$$

Rearrangement gives the coefficient of permeability

$$k = \frac{C_v\ a_v\ \gamma_w}{(1 + e)} \qquad (4\text{-}35)$$

for a given void ratio, coefficient of consolidation, and coefficient of compressibility, equation 4-35 gives the coefficient of permeability. Although this procedure is indirect in nature, it has the advantage of being simple and permits a check on changes in k for the different degrees of decomposition.

E. Vane Shear Strength

The conventional method of obtaining undisturbed soil samples and performing unconfined compression or triaxial tests has met limited success with organic soils. The difficulty in preparing samples for testing, and the high strain-to-failure characteristics of organic soils have resulted in a preference for using vane shear tests over other conventional methods.

In the test program a miniature vane shear apparatus was used for strength determinations at selected consolidation pressures after various degrees of decomposition. A photograph of the device used is shown in Fig. 4-4.

The vane apparatus comes with three vane sizes. These vanes are made of steel and are chromium plated for protection against corrosion. The vane, mounted in a rotating socket, is retained by a knurled fixing screw. This socket rotates in a ball seating. Four calibrated springs are supplied, each with its own deflection/load chart. For convenience these charts were used to derive equations for each spring.

If the vane is prevented from rotating and the hand knob is turned in a clockwise direction (a motor was available for vane rotation when desired) the circular graduated scale rotates and a torque is applied to the spring. The load applied can be determined by noting the angular deflection from the graduated scale and reading the relevant spring and vane constants. Determination of the vane shear strength for the soils was made as follows:

$$S_U = \frac{M}{C} \tag{4-36}$$

where S_U = undrained shear strength, M = torque required to shear the soil, C = a constant dependent on the dimension and shape of the vane used, thus

$$C = \frac{D^2 H}{2}\left(1 + \frac{D}{3H}\right) \tag{4-37}$$

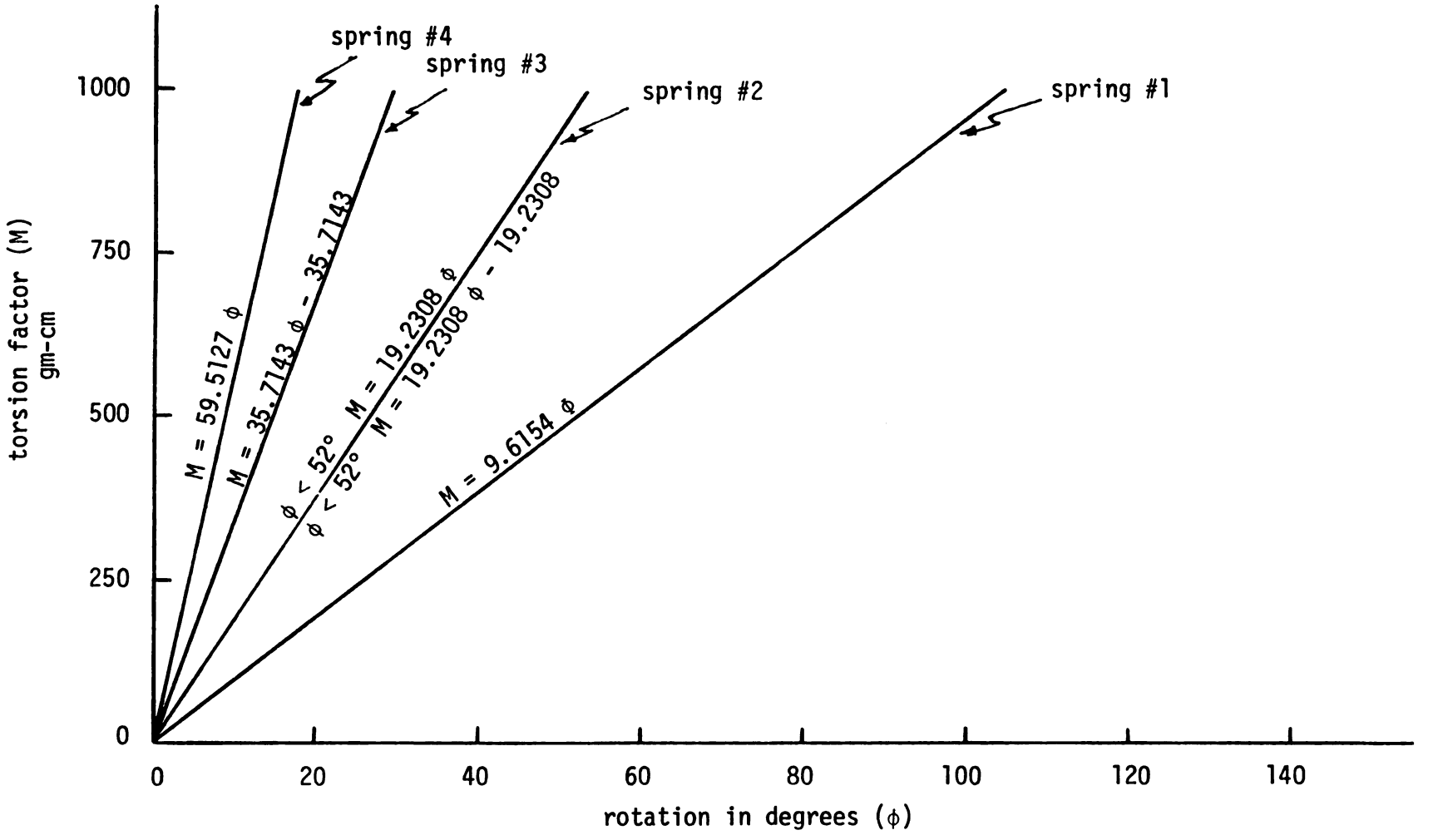


Figure 4.5.--Calibration curves for miniature vane shear apparatus.

This equation was applicable if both ends of the vane effectively sheared the sample. The torque M was obtained from the position of the pointer on the scale when failure takes place and the appropriate spring constant.

For this project spring #1 was used. The vane with dimensions of 1/2 by 1 inch gave the equation:

$$S_U = 1.2807\ \phi \qquad (4\text{-}38)$$

where ϕ = pointer rotation in degrees. Note that for spring #1 $M = 9.6154\ \phi$ and for the 1/2 by 1 inch vane size, $C = 7.51\ cm^3$. Thus, $S_U = \frac{M}{C} = k\phi = \frac{9.6154}{7.51}\ \phi = 1.2807\ \phi$. The different equations relating M to ϕ are shown in Fig. 4-5.

F. Environmental Control and Sample Storage

For the aerobic decomposition process a humid room was used for storing the samples. The temperature was maintained at about 35°C and the humidity kept close to 100%.

For the anaerobic decomposition process, the samples were stored in an insulated compartment 3 ft by 3 ft by 5 ft. A 500 watt heat lamp provided the heat source. An aluminum foil umbrella placed above the heat lamp helped to maintain a uniform temperature throughout the storage compartment. A thermosensing device placed inside the compartment controlled the heat lamp so as to maintain temperature in the range of 33 to 37°C. These temperatures were well within the mesophilic range.

In Stage I through II, beakers were adjusted to a pH level of approximately 7.0, at 15 day intervals. The purpose was to maintain a pH level favorable for methane and acid forming bacteria, hence, a balanced anaerobic process. In Stages III-0 through III-7 the pH was maintained at 7.0 each week. Sodium bicarbonate was added by successive trials until the pH was close to or at 7.0. Experience gained in Stages I and II proved valuable in reducing the number of trials needed for bringing the pH up to the desired level.

CHAPTER V

EXPERIMENTAL RESULTS

A. Organic Content Determination

The standard method for ash content (ASTM D586-63) and the MacFarlane recommended procedure for organic content determination, reviewed in Chapter II, could err by approximately 15%. An error of this magnitude could not be tolerated in this research program, hence efforts were made to minimize any errors. This effort lead to the development of a new test procedure.

1. Two Component Soil System

A two component soil system is defined as any soil having only two materials with different thermal characteristics, e.g., cellulose and kaolinite or kaolinite and sand, etc. In this research project, pulp fiber was used as the organic matter and kaolinite as the mineral fraction in all samples. These materials were tested for their thermal characteristics.

The percent weight reduction (W_r) of the cellulose pulp fiber has been plotted against duration (D) of combustion for different temperatures (T) in Fig. 5.1(a). The same data can be presented as weight reduction versus temperature for different durations as shown in Fig. 5.1(b). For some applications the data may be presented as

shown in Figure 5.2 with temperature plotted against duration for different percents of weight reduction.

A second set of samples, containing all kaolinite was tested and plots similar to those obtained for all cellulose were made, as shown in Fig. 5.3. Note that the data for kaolinite and cellulose reveal that the organic content can easily be determined using linear combinations of weights and weight reduction factors. An infinite number of ways are possible for determining the organic content, most of which require only partial combustion of the organic matter.

Two assumptions made for the new test procedure include:

1. The soil mineral type is known,
2. The organic matter type is known.

Both of these conditions were satisfied since pulp fibers were used for this organic fraction and kaolinite was used as the mineral fraction.

Determination of organic content without complete combustion is illustrated by the following example. Assume that an organic sample containing pulp fiber and kaolinite has a weight (WT_0) and that the duration and temperature of combustion were 0.5 hour and 400°C, respectively. Assume that WT_1 was the weight of the sample after combustion. Determine the cellulose content?

The solution should proceed as follows: From Fig. 5.1 for T = 400°C and D = 0.5 hour obtain C_2 (T, D) = 0.12 (this corresponds to the weight of cellulose remaining at T and D). From Fig. 5.3 for T = 400°C and D = 0.5 hour obtain C_1 = 0.99. Now using Equation 4-5, compute

$$X_{FO} = \frac{0.99 - (WT_1/WT_0)}{0.99 - 0.12} = 1.14 - 1.15 \left(\frac{WT_1}{WT_0}\right)$$

From equation 4-6, obtain

$$X_{CO} = 1 - X_{FO} = -0.14 + 1.15 \left(\frac{WT_1}{WT_0}\right)$$

The advantage of incomplete combustion is that shorter times and lower temperatures are required for running a test.

2. n-Component Soil System

For a soil mass with n-different types of minerals and/or organic materials, the organic and mineral content can be determined by the following procedure. Assume that n-different soil components exist in a soil mass and that curves similar to that of Fig. 5.1, have been derived for each of these components. Choose as many temperature combinations and duration periods as that of the number of components (n) and set up the following equations:

$$\begin{aligned}
(T_1, D_1) &\rightarrow C_{11} X_1 + C_{12} X_2 + \ldots + C_{1n} C_n = W_1 \\
(T_2, D_2) &\rightarrow C_{21} X_1 + C_{22} X_2 + \ldots + C_{2n} X_n = W_2 \qquad (5\text{-}1) \\
&\;\;\vdots \\
(T_n, D_n) &\rightarrow C_{n1} X_1 + C_{n2} X_2 + \ldots + C_{nn} X_n = W_n
\end{aligned}$$

where C_{11}, C_{12}, . . . C_{nn}, are constants dependent on the choice of T and D, sample weights W_1, W_2, . . . W_n correspond to the respective values of T and D, and X_1, X_2 . . ., X_n are weights of the components present in the sample. A solution to the n x n equations (5-1) for X_1, . . ., X_n, gives the percent content of each of these components. This simple procedure may also be used in the classification of soils having an appreciable amount of clay, in addition to the soil organic contents.

The preceding analysis can be presented in an abbreviated form:

$$\sum_{i=1}^{n} C_{ji} X_i = W_j \qquad j = 1, 2, \ldots, n \tag{5-2}$$

where i is the dummy index which represents the i-th component of the soil sample, j is a dummy index which represents the j-th combination of (T) and (D), C_{ij} is the percent weight remaining of the i-th component for the j-th combination of (T) and (D), X_i is the weight of the i-th component, and W_j is the total weight of all components at the j-th combination of (T) and (D). An application of equation (5-2) is shown below. Assume that a soil contains cellulose, kaolinite, and sand. Set up the equations that are needed for determining the component weights and consequently their percentages by weight in that soil.

Note that for three components $n=3$ and that by summing equation (5-2) over i gives:

$$C_{j1}X_1 + C_{j2}X_2 + C_{j3}X_3 = W_j$$

Now, three combinations of T and D are selected, to give:

$$j = 1 \rightarrow (T_1, D_1) \rightarrow C_{11}X_1 + C_{12}X_2 + C_{13}X_3 = W_1$$

$$j = 2 \rightarrow (T_2, D_2) \rightarrow C_{21}X_1 + C_{22}X_2 + C_{23}X_3 = W_2$$

$$j = 3 \rightarrow (T_3, D_3) \rightarrow C_{31}X_1 + C_{32}X_2 + C_{33}X_3 = W_3$$

Select C_{11}, C_{21}, C_{31} from the cellulose curves given in Fig. 5.1, C_{12}, C_{22}, C_{32} from the kaolinite curves given in Fig. 5.4, and C_{13}, C_{23}, C_{33} for sand, which experiences very small weight loss due to dehydration in comparison to clay, can be easily determined. Note that for the sand $C_{13} = C_{23} = C_{33} = 1.0$ for temperatures greater than 100°C for any duration D. Solve these equations for the three contents X_1, X_2, and X_3 (note that the three combinations of T's and D's determine W_1, W_2, and W_3). Knowing X_1, X_2, and X_3, the kaolinite, sand, and cellulose contents are determined as follows:

$$\text{Percent Kaolinite} = \frac{X_1}{W_1}$$

$$\text{Percent sand} = \frac{X_2}{W_1}$$

$$\text{Percent cellulose} = \frac{X_3}{W_1}$$

where W_1 is the initial total weight of the sample (after drying at T = 100°C).

3. General Approach

In general, the mineral type and organic material contained in a soil are not known in advance. The methods outlined in the previous sections will be of little or limited value although they were essential for this particular research, since component types were known in advance. As a result an extensive effort was made to define a procedure for calculating the organic content of a soil mass irrespective of its organic or mineral composition. The main problems encountered in organic content determination involves the different clay types. Consequently, dehydration curves for the main clay minerals (kaolinite and montmorillonite) were derived. These curves show that, kaolinite will lose up to 14% of its weight due to dehydration at temperatures greater than 550°C (Fig. 5.3). Montmorillonite was shown to lose about 6% of its weight at 100°C and then loses an additional 7% of its weight at higher temperatures (Fig. 5.4). Note that the kaolinite and montmorillonite for which dehydration curves were derived represent only specific types. Other kaolinite and montmorillonite soils exhibit different dehydration behaviors from those in Fig. 5.3 and 5.4, as is shown in Fig. 5.5. Close inspection of these dehydration curves bring out two important facts:

1. For the kaolinite group, the dehydration curves approximate one curve if weight losses are based on 100°C dry weight. The same is true for the montmorillonite group,

2. Dehydration weight losses for most other clay minerals fall between that of the kaolinite and montmorillonite soils (Fig. 5.5d).

The problem is simplified if all samples used in organic content determinations are dried first at 100°C. Consequently, dehydration

curves for cellulose, kaolinite, and montmorillonite, with a duration of one hour and dried initially at 105°C are plotted in Fig. 5.6(a). Note that complete combustion of cellulose was less than 100% for the maximum temperature of 900°C. A similar plot with duration time of 12 hours [Fig. 5.6(b)] shows that 100% combustion of cellulose occurs at approximately 370°C. Note that both kaolinite and montmorillonite lose an average of only 1.5% by weight due to dehydration for temperatures up to 430°C and duration of 12 hours. These facts permit the following assumptions to be made for the proposed new method for organic content determination.

1. Nonclay minerals, e.g., sand, lose about 1% of their weight irrespective of temperature provided they are initially dried at 105°C,

2. Complete combustion of cellulose (source of most organic matter in soil) occurs at temperatures close to 400°C and a duration of 12 hours,

3. The dehydration weight loss of kaolinite and montmorillonite heated to 400°C is about 1.5% based on oven dry weights.

The proposed new method permits determination of organic content for natural soils without regard for mineral content or origin of organic matter. The procedure, step by step, is as follows:

1. Dry the soil sample at 105°C for 24 hours (10-20 gm is adequate).

2. Heat the sample to 400°C and maintain this temperature for 12 hours.

3. Solve the following equations for the weight of organic matter and mineral solids (Equation 5-1).

$$C_{11}X_1 + C_{12}X_2 = W_1$$

$$C_{21}X_1 + C_{22}X_2 = W_2$$

For D = 12 hours and T = 400°C Fig. 5.6(b) gives the following coefficients: $C_{11}(100, 12) = 1.00$, $C_{12}(100, 12) = 1.00$, $C_{21}(400, 12) = 0.985$, $C_{22}(400, 12) = 0$. Note that X_1 is the mineral weight, X_2 is the weight of organic matter, W_1 is the weight of sample at 105°C, and W_2 is the sample weight after combustion at T = 400°C and D = 12 hours. Substituting these values into the equations gives:

$$X_1 + X_2 = W_1$$

$$0.985\ X_1 + 0 = W_2$$

The general solution is now determined as follows:

$$X_1 = 1.02\ W_2 \qquad (5\text{-}3)$$

$$X_2 = W_1 - 1.02\ W_2 \qquad (5\text{-}4)$$

Compute the mineral content from Equation (5-3):

$$X_{MI} = 1.02\ \frac{(W_2)}{(W_1)} \qquad (5\text{-}5)$$

Compute the organic content from Equation (5-4)

$$X_{FI} = \frac{W_1 - 1.02\ W_2}{W_1} = 1 - 1.02\ \left(\frac{W_2}{W_1}\right) \qquad (5\text{-}6)$$

B. Vane Shear Strength and Consolidation Parameters (Initial Conditions)--Stage I

Both aerobic and anaerobic samples were tested in this stage so that the various engineering parameters could be established in terms of the carbon to nitrogen ratios and organic contents. A block diagram in Appendix A-O shows the makeup of aerobic and anaerobic samples.

1. Aerobic Samples

a. Organic content effects.--A miniature vane shear apparatus was used for determination of the undrained shear strength, and a modified consolidometer for consolidation parameters. The test results for the various parameters were plotted so that initial conditions were established.

The coefficient of consolidation versus organic content was plotted for carbon/nitrogen ratios of 5, 10, 30, and 50 to one (Fig. 5.7). The coefficient of compressibility was plotted against the organic content for C/N ratios of 5, 10, 30, and 50 to one (Fig. 5.8). Curves showing the coefficient of permeability versus the organic content are given in Fig. 5.9, for the various C/N ratios. The vane shear strength was shown to increase with increasing organic content irrespective of C/N ratio (Fig. 5.10).

Plots of void ratio and compression index versus the organic content are given in Figs. 5.11 and 5.12, respectively. The general trend appears to be an increase in void ratio and compression index with increasing organic content, and this was not altered by the C/N ratio.

b. Nutrient effects.--For an aerobic decomposition process to be successful, the moisture content must be maintained at certain levels. Consequently, the degree of saturation is not necessarily 100%. The implication is that conventional methods for determining the various consolidation parameters (assume 100% saturation) were used. However, the results obtained for the aerobic samples can still be useful in relative terms, e.g., relating decomposed to undecomposed sample parameters under the same test conditions.

The coefficient of consolidation versus C/N ratio for organic contents of 30, 60, and 80 are shown in Fig. 5.13. The permeability was also plotted against C/N ratio in Fig. 5.14.

2. Anaerobic Samples

a. Organic content effects.--Since anaerobic conditions require the exclusion of oxygen from all samples, this condition was easily accomplished by saturating all samples. Consequently, most assumptions for the conventional consolidation theory were satisfied. The carbon to nitrogen ratios of 5, 10, 30, 50, 200, and ∞ will be referred to by C/N in this section.

The coefficient of consolidation was plotted against the organic content for the different C/N ratios in Fig. 5.15. Curves representing the coefficient of compressibility versus organic content for various C/N ratios and two nitrogen sources are shown in Fig. 5.16.

The coefficient of permeability was shown to increase with increasing organic content for all C/N ratios (Fig. 5.17). The vane

shear strength increased as the organic content increased. Curves exhibiting this behavior for the C/N ratios are shown in Fig. 5.18. A summary of compression index and void ratio data plotted against organic content for all C/N ratios, is given in Figs. 5.19 and 5.20, respectively.

b. Nutrient and pH effect.--In order to isolate the nutrient effects on the various consolidation and shear strength parameters, they are plotted against the C/N ratio. Additional information relating some parameters to the pH are also introduced.

The coefficient of consolidation versus C/N ratio was plotted for organic contents of 30, 60, and 80%, and consolidation pressures of 11.6, 23.3, and 34.9 gm/cm^2 (Fig. 5.22). An interesting fluctuation in the coefficient of compressibility versus C/N ratio appears to take place regardless of the organic content and consolidation pressure (Fig. 5.23).

A large increase in permeability was observed in samples with high organic contents irrespective of C/N ratio. However, the C/N ratio does have an effect on the absolute value of permeability as shown in Fig. 5.24. The vane shear strength was plotted against the C/N ratio for organic contents of 30, 60, and 80% as shown in Fig. 5.25. A second plot showing vane shear strength as a function of pH level is given in Fig. 5.26. The compression index, coefficient of secondary compression, equivalent liquid limit, and void ratio versus the C/N ratio are summarized in Figs. 5.27, 5.28, 5.29, and 5.30, respectively.

C. Decomposition Effects on Shear Strength and Consolidation Parameters (Final Conditions)-- Stage II

The aerobic and anaerobic samples tested for initial conditions were allowed to decompose for 60 days under a favorable environment. The effect of decomposition on the various consolidation and vane shear strength parameters are compared in terms of the changes from initial conditions.

1. Aerobic Samples

Considerable changes in magnitude of the consolidation and strength parameters took place as a consequence of the decomposition process. The following figures include plots of some of the parameters important to geotechnical engineers.

The percent decomposition versus carbon to nitrogen ratio is shown in Fig. 5.31. This particular curve is important because it shows the rate of decomposition. The amount of decomposition is seen to be largely influenced by the clay content of the substrate.

Ratios of decomposed to initial values for the coefficient of consolidation, coefficient of compressibility, coefficient of permeability, vane shear strength, coefficient of secondary compression, and height are plotted against decomposition and initial C/N ratios (5, 10, 30, and 50) in Figs. 5.32, 5.33, 5.34, 5.35, 5.36, and 5.37, respectively.

2. Anaerobic Samples

After allowing the anaerobic samples to decompose for a two-month period, they were tested for their consolidation and strength parameters. A summary of the more important findings are expressed in the figures shown below.

The percent decomposition is plotted against the initial carbon to nitrogen ratio (Fig. 5.38). The effect of the initial clay content is distinctly different from that of the aerobic samples. This fact is shown by the ultimate degree of decomposition reached in samples of 30, 60, and 80% organic content.

The ratios (decomposed to initial value) of the coefficient of consolidation, coefficient of compression, coefficient of secondary compression, shear strength, equivalent liquid limit, height, and void ratio versus decomposition were plotted for initial carbon to nitrogen ratios of 5, 10, 30, 50, 200, and ∞ and for initial organic contents of 30, 60, and 80. These plots are shown in Figs. 5.38, 5.39, 5.40, 5.41, 5.42, 5.43, 5.44, and 5.45, respectively.

D. Decomposition Effects on Shear Strength and Consolidation Parameters for a Fixed C/N-- Stage III

In this stage the C/N ratio was fixed at 30:1 so that the relative effect of nutrients could be eliminated. Gas effects were also studied by adding sodium bicarbonate before and after testing duplicate samples. However, no direct measurement of gas content was made.

The samples, all of which contained initial organic contents of 30, 60, and 80%, were tested for initial condition (at time zero) and subsequently for several periods of decomposition (7, 14, 21, 35, and 49 days) detention time.

The ratios (decomposed to initial value) of the coefficient of consolidation versus decomposition were plotted for initial organic contents of 30, 60, and 80% as shown in Fig. 5.46. The compression index was seen to increase by varying amounts with decomposition depending on the initial organic content as shown in Fig. 5.47. The ratios (decomposed to initial value) of compression index and permeability versus decomposition are shown in Figs. 5.48 and 5.49, respectively.

The undrained vane shear strength was plotted against percent decomposition for consolidation pressures of 5.81 and 11.6 gm/cm^2 as shown in Fig. 5.50. Additional figures showing the equivalent liquid limit and ratios (decomposed to initial value) of liquid limit were also plotted in Fig. 5.51 and Fig. 5.52, respectively. The ratios (decomposed to initial value) of height and void ratio versus decomposition are shown in Figs. 5.53 and 5.54, respectively.

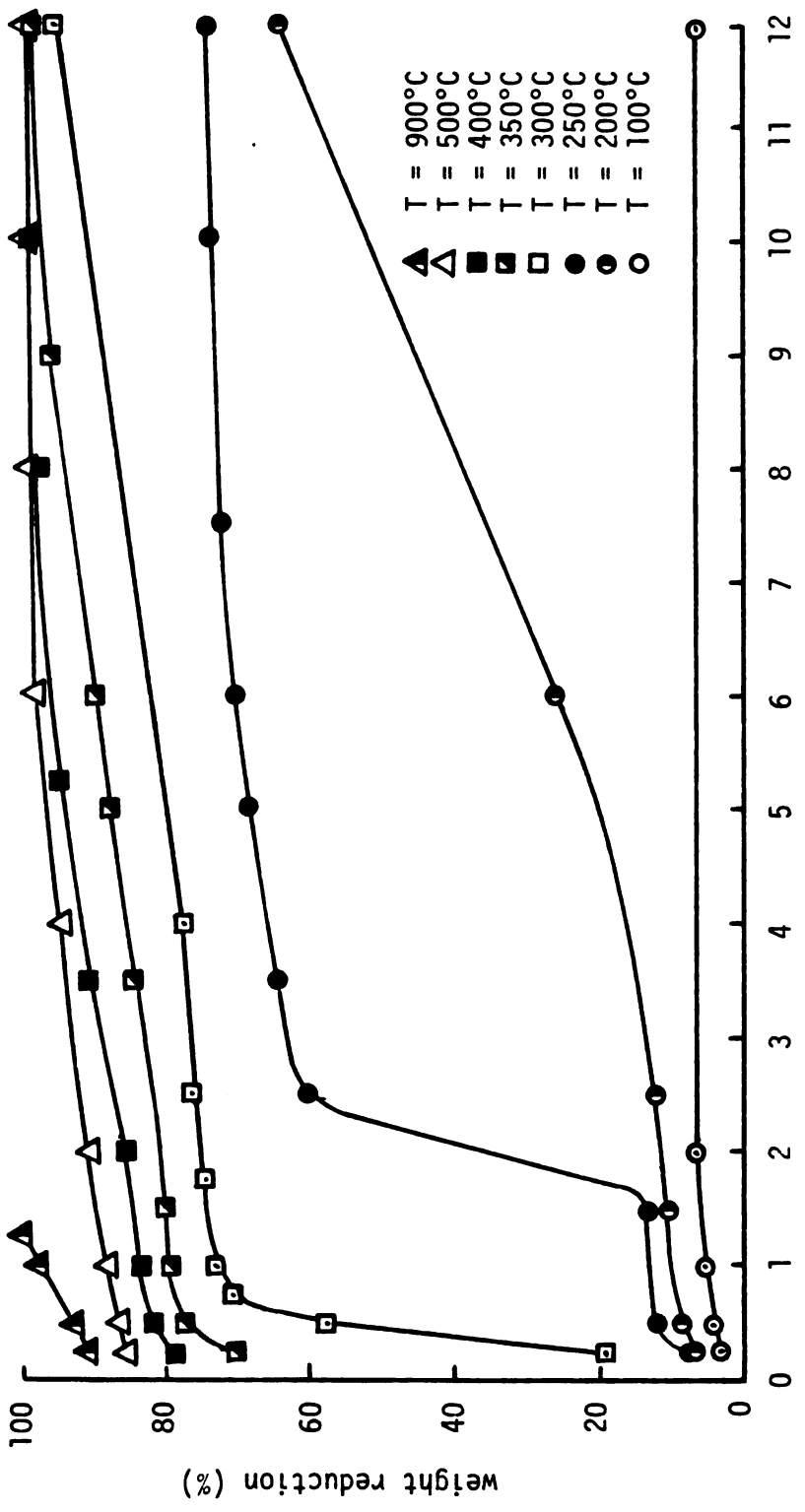


Figure 5.1.--Percent weight reduction for cellulose (a) duration dependence. (b) temperature dependence.

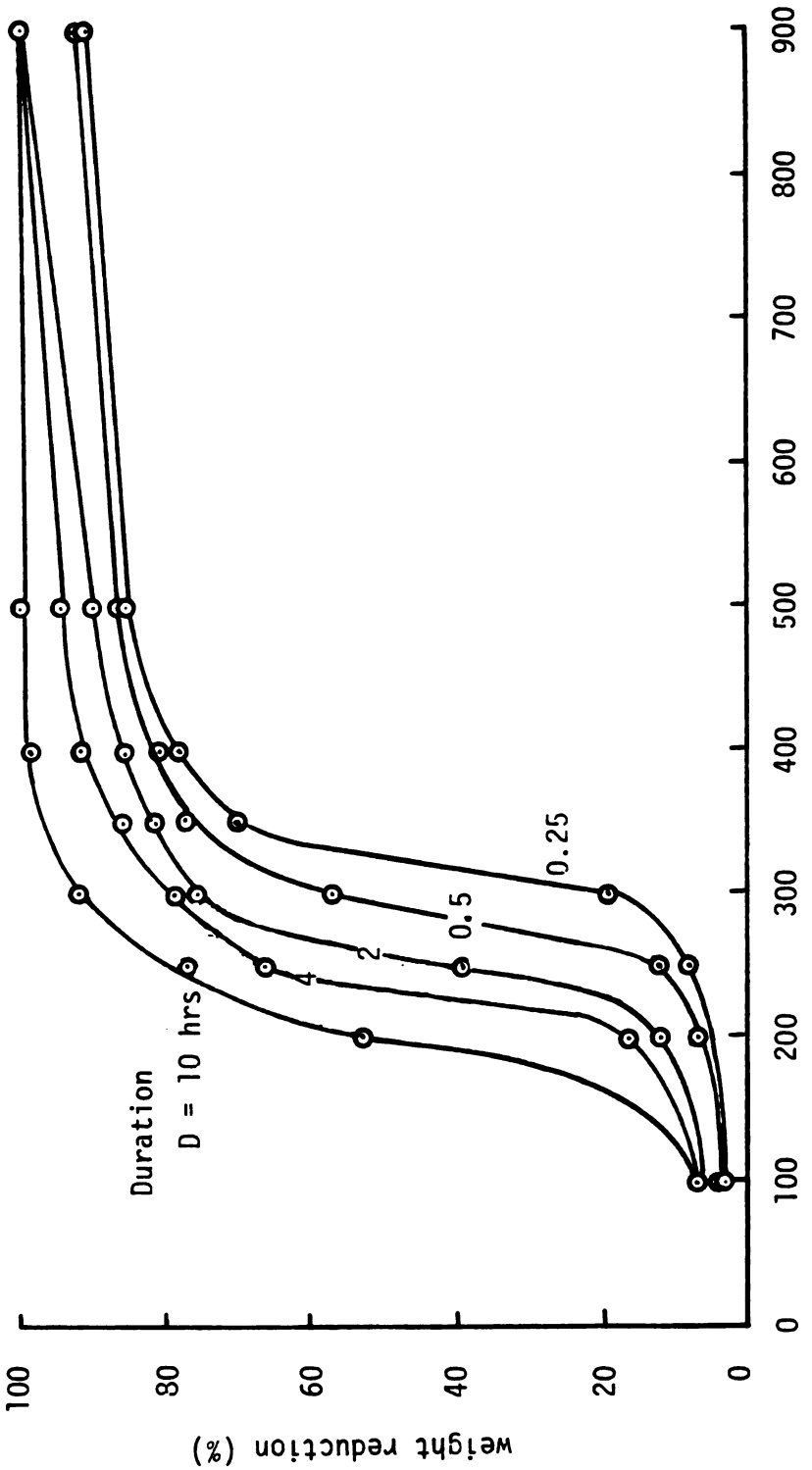


Figure 5.1.--Continued.

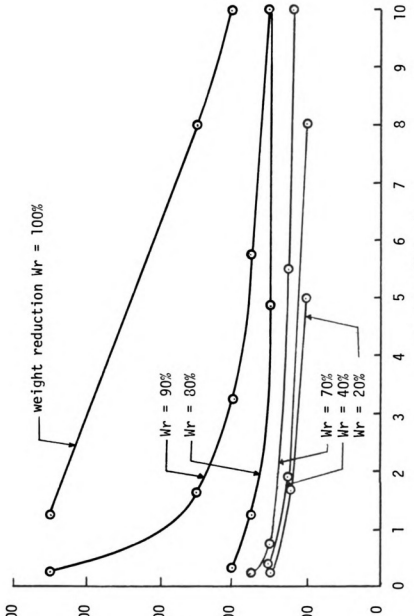
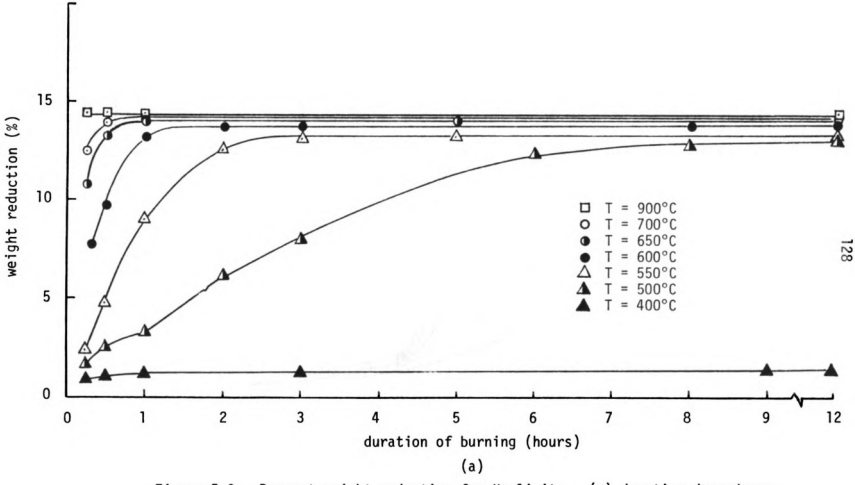


Figure 5.2.--Temperature versus duration for different percents weight reduction, cellulose.



(a)

Figure 5-3.--Percent weight reduction for Kaolinite. (a) duration dependence. (b) temperature dependence.

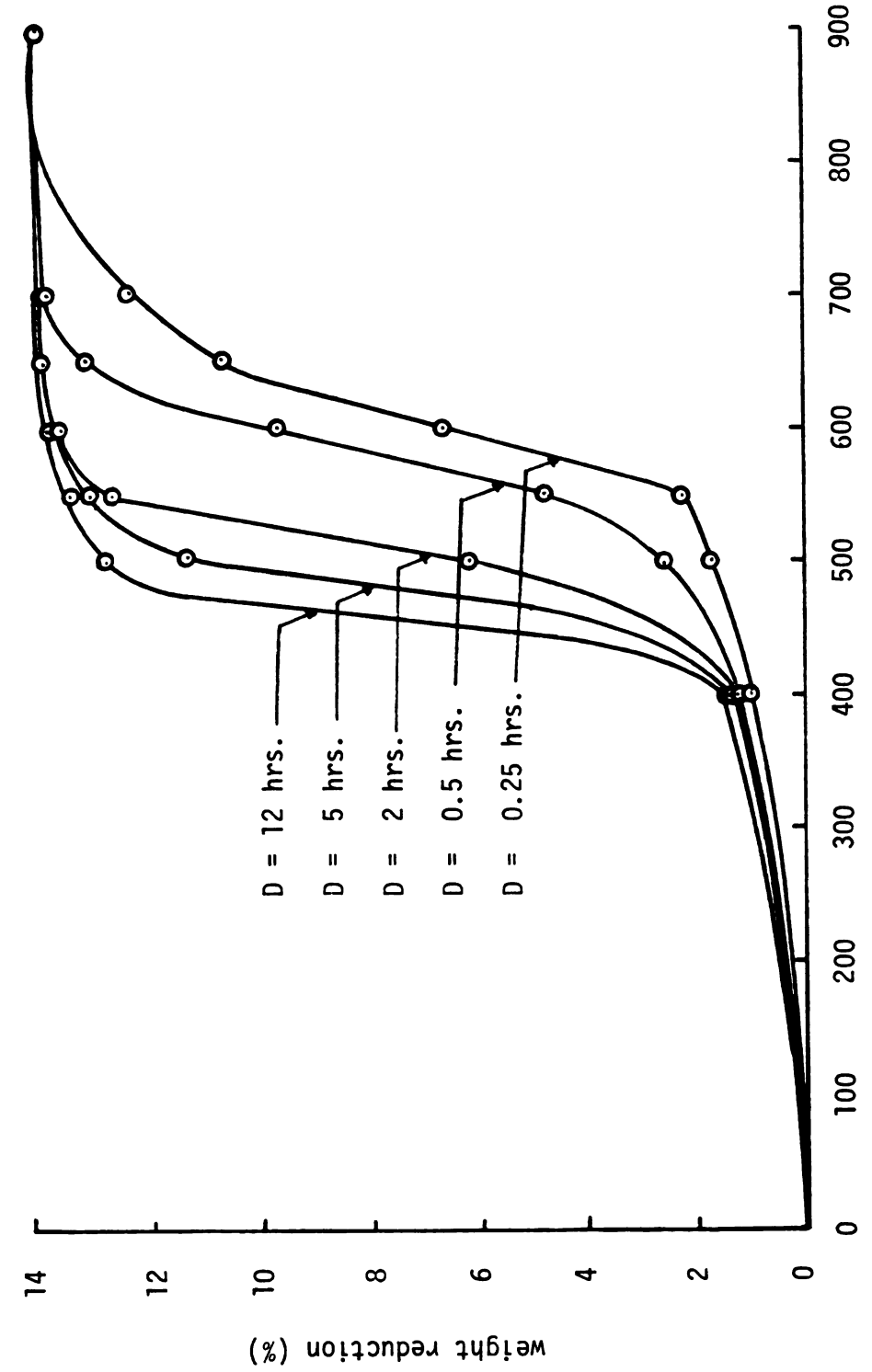


Figure 5.3.--Continued.
(b)

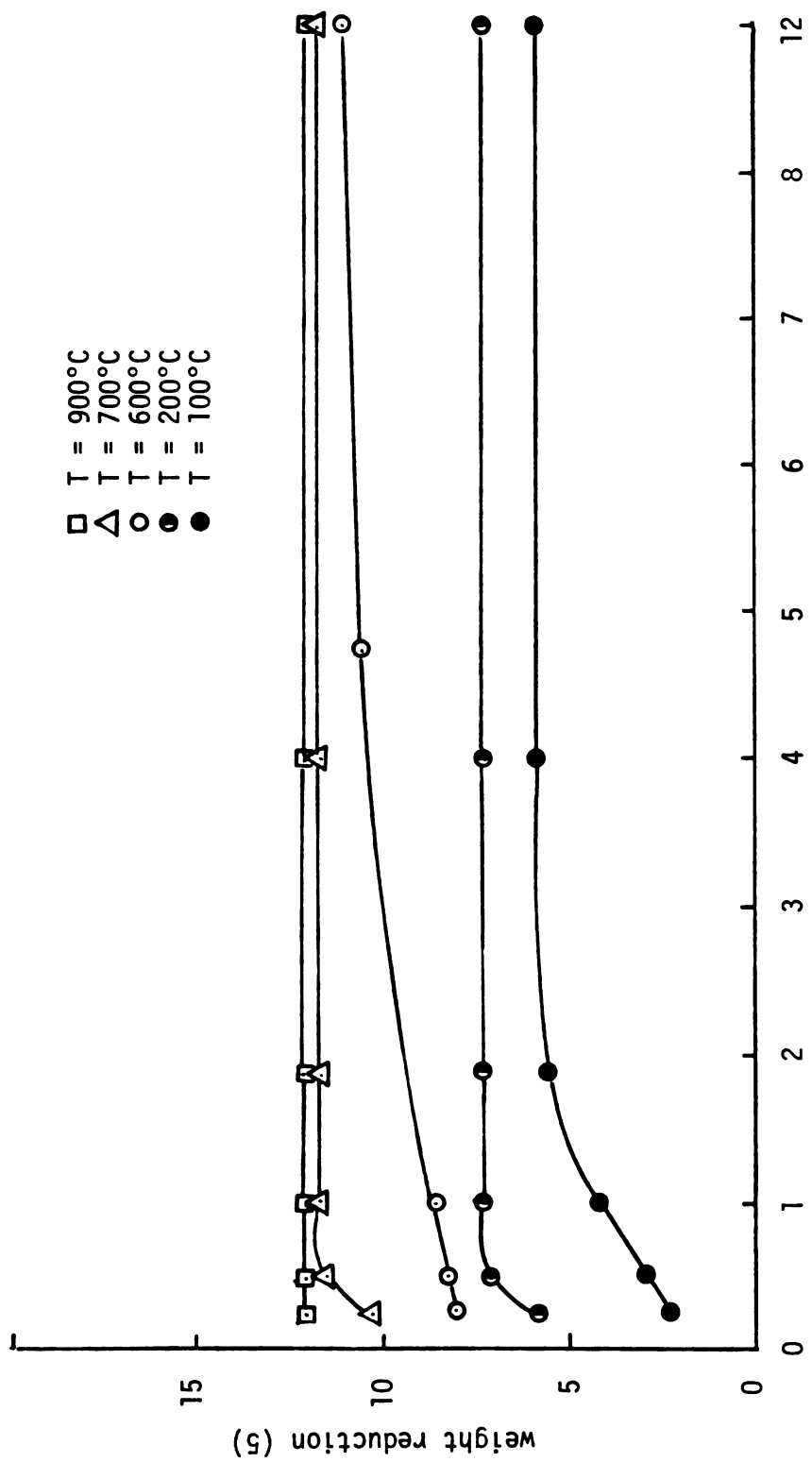


Figure 5.4.--Percent weight reduction for Montmorillonite. (a) duration dependence. (b) temperature dependence.

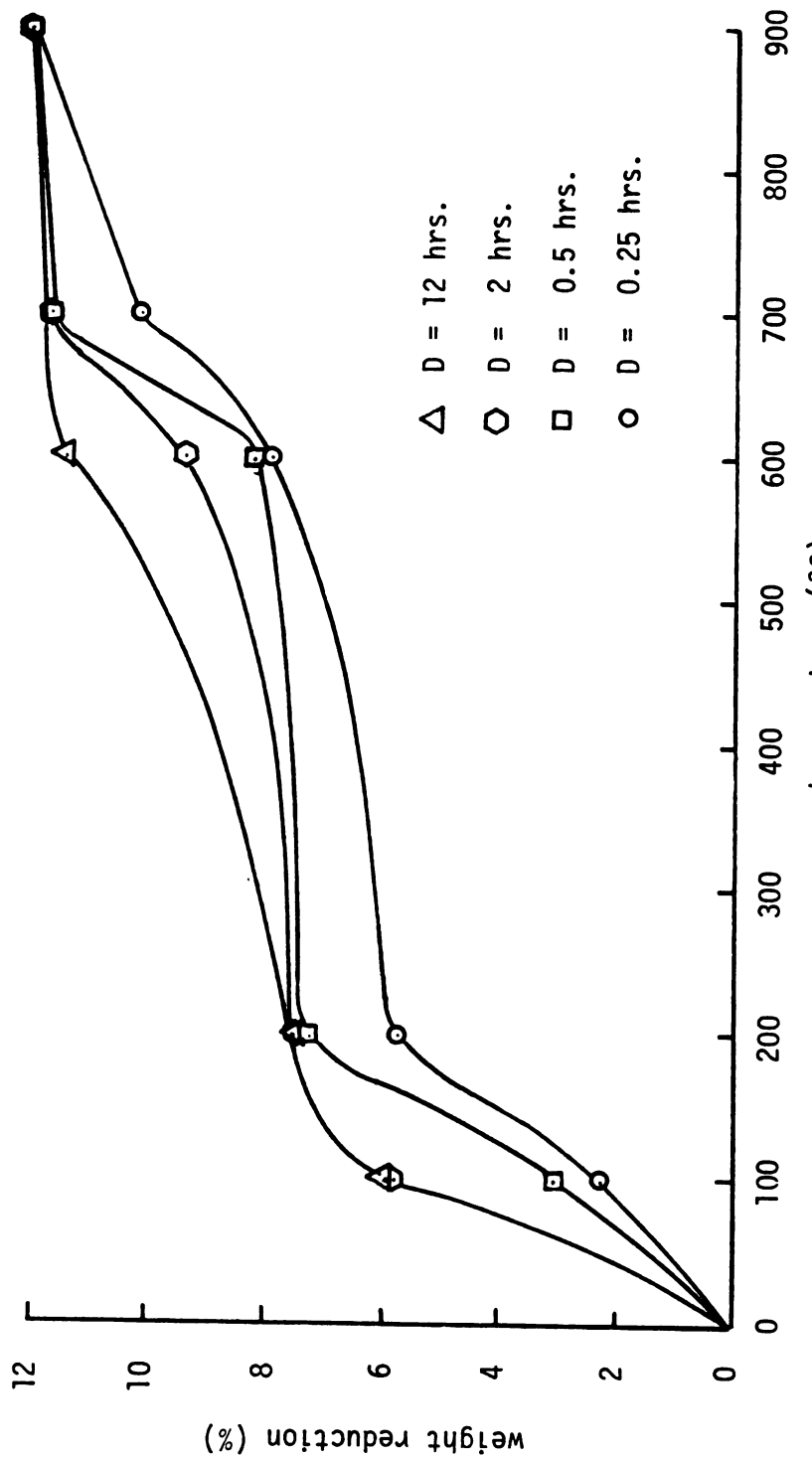
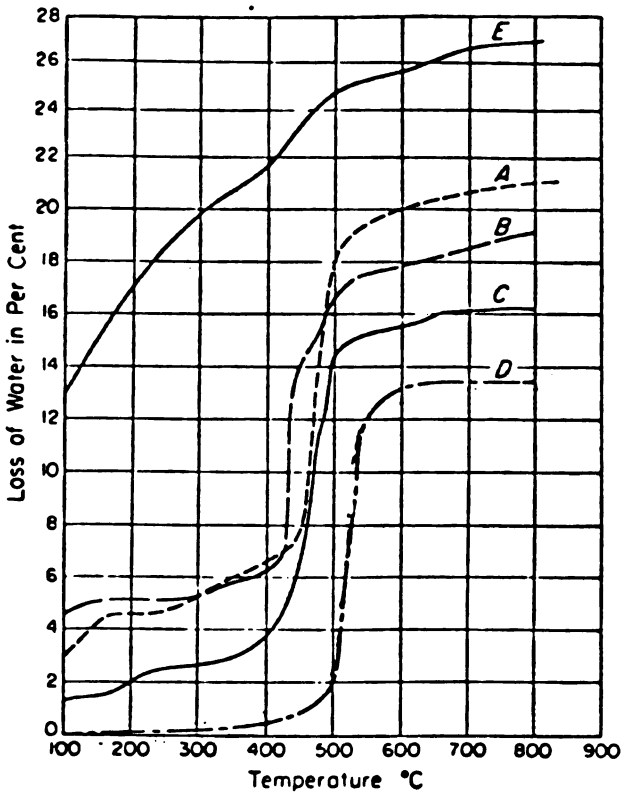


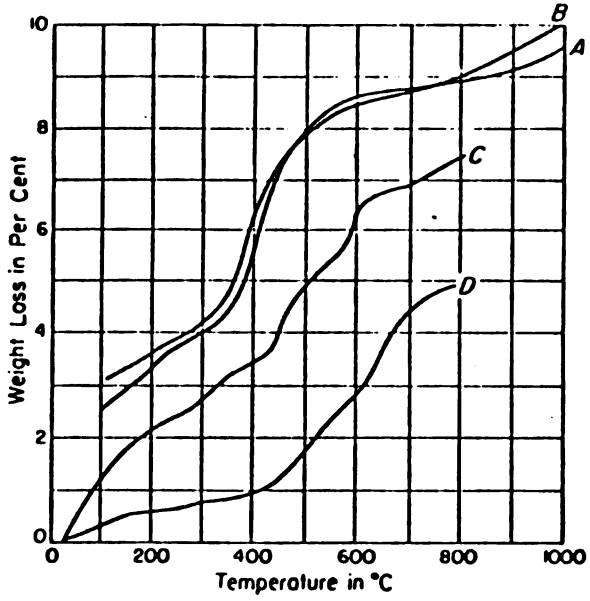
Figure 5.4.--Continued.



Dehydration curves, from Ross and Kerr.[5,6] (*A*) Halloysite, Liége, Belgium; (*B*) halloysite, Adams County, Ohio; (C) halloysite, Hickory, North Carolina; (*D*) kaolinite, Ione, California; (*E*) allophane, Moorefield, Kentucky.

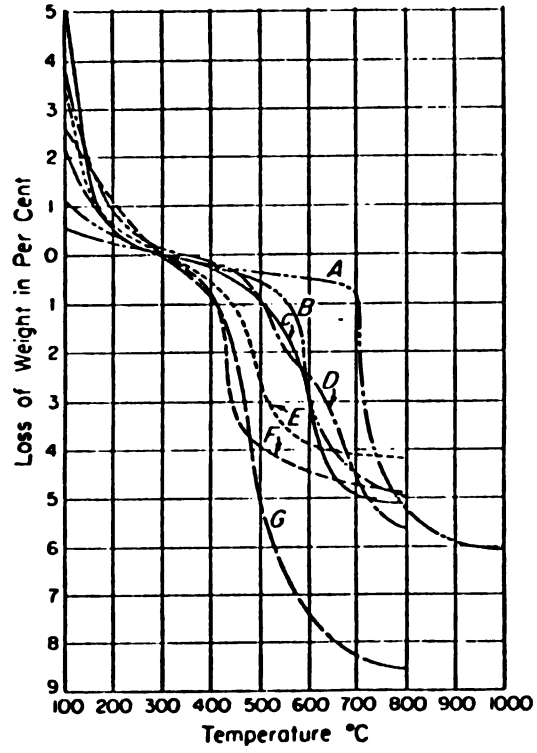
(a)

Figure 5.5.--Dehydration curves. (a) Halloysites (after Ross and Kerr, 1931 and 1934). (b) Illites (after Grim, et al., 1937). (c) Montmorillonite (after Ross and Hendricks, 1945). (d) Natural clay (Kelley, et al., 1936).



Dehydration curves, from Grim, Bray, and Bradley.[11] (*A*) Illite, Gilead, Calhoun County, Illinois; (*B*) illite, Fithian, Vermilion County, Illinois; (*C*) muscovite, very finely ground; (*D*) muscovite, 100 mesh (coarser than *C*).

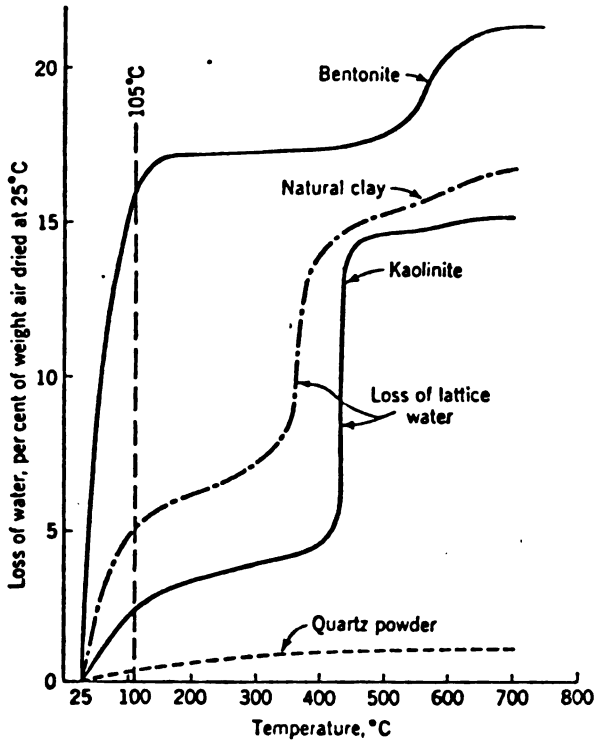
(b)



Dehydration curves, from Ross and Hendricks.[11] (*A*) Hectorite, Hector, California; (*B*) montmorillonite, Belle Fourche, South Dakota; (*C*) montmorillonite, Tatatilla, Mexico; (*D*) montmorillonite, Montmorillon, France; (*E*) nontronite, Spokane, Washington; (*F*) nontronite, Sandy Ridge, South Carolina; (*G*) montmorillonite, Pontotoc, Mississippi.

(c)

Figure 5.5.--Continued.



. Dehydration curves showing loss of lattice water.

(d)

Figure 5.5.--Continued.

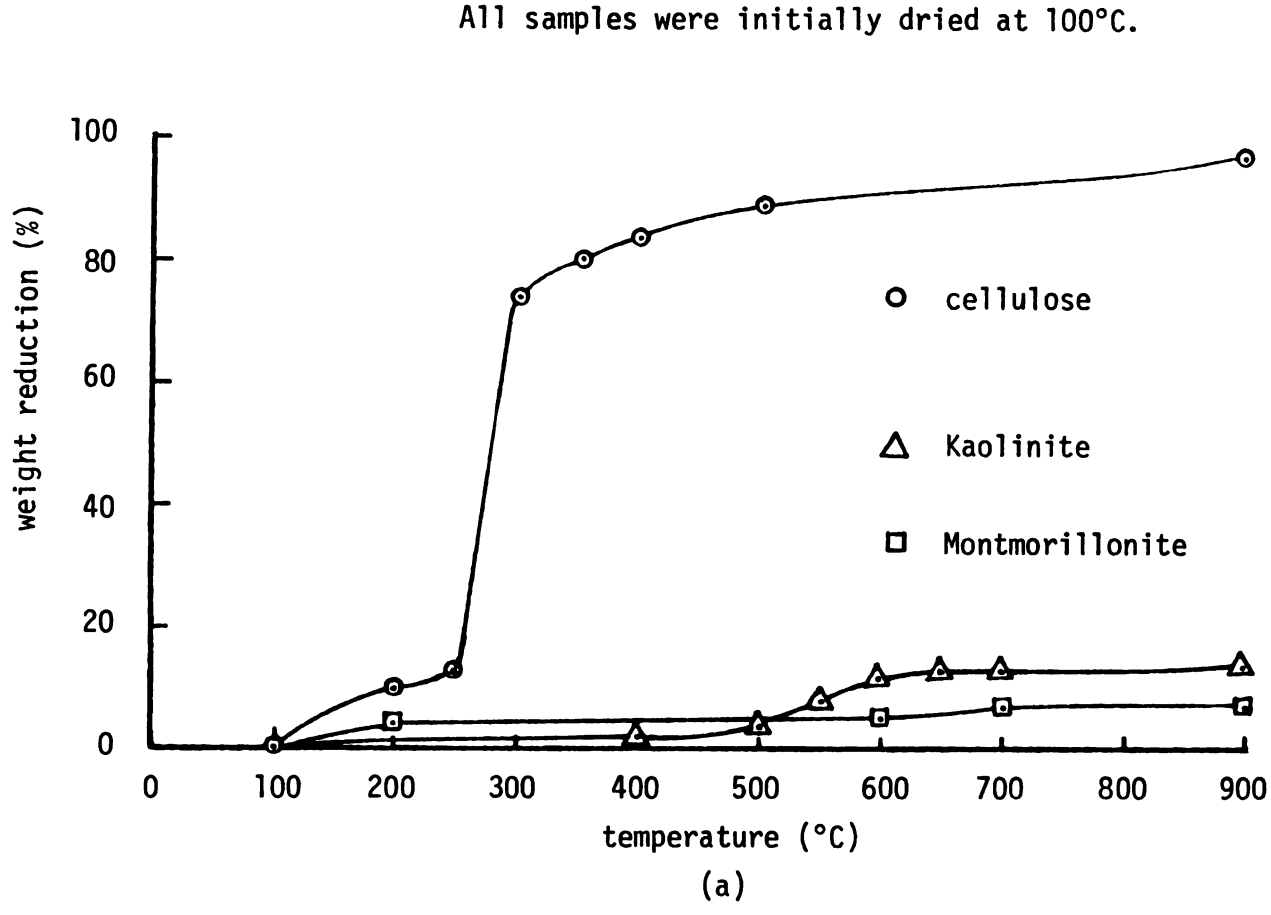
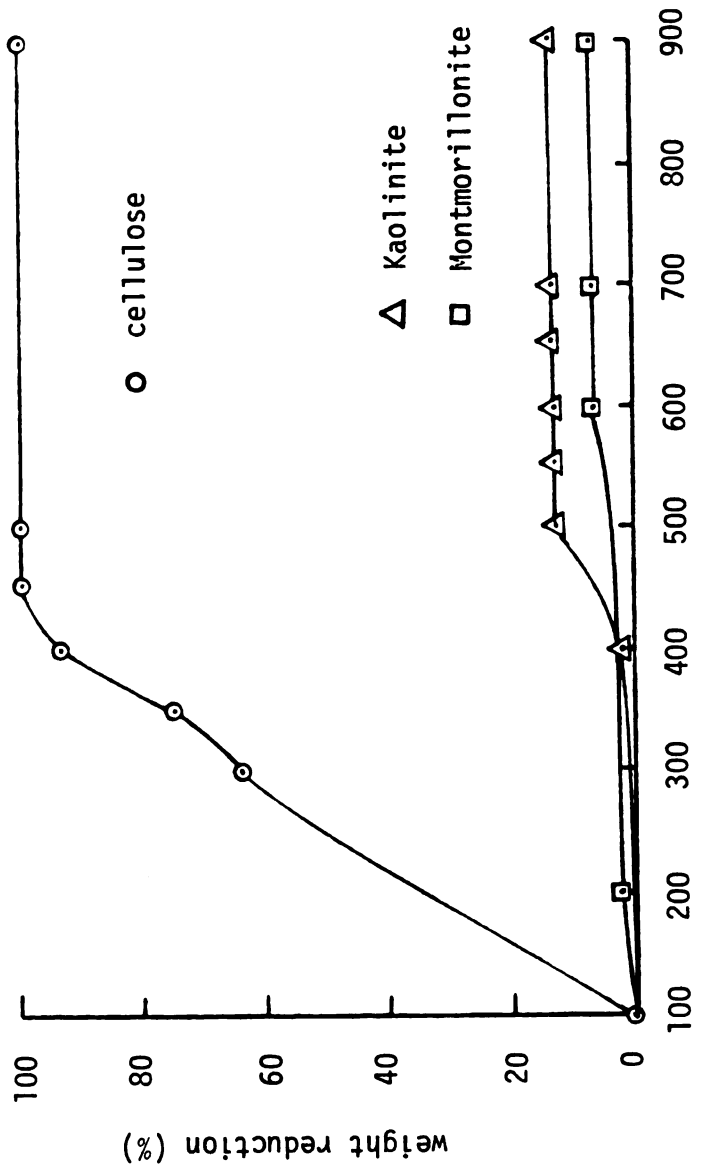
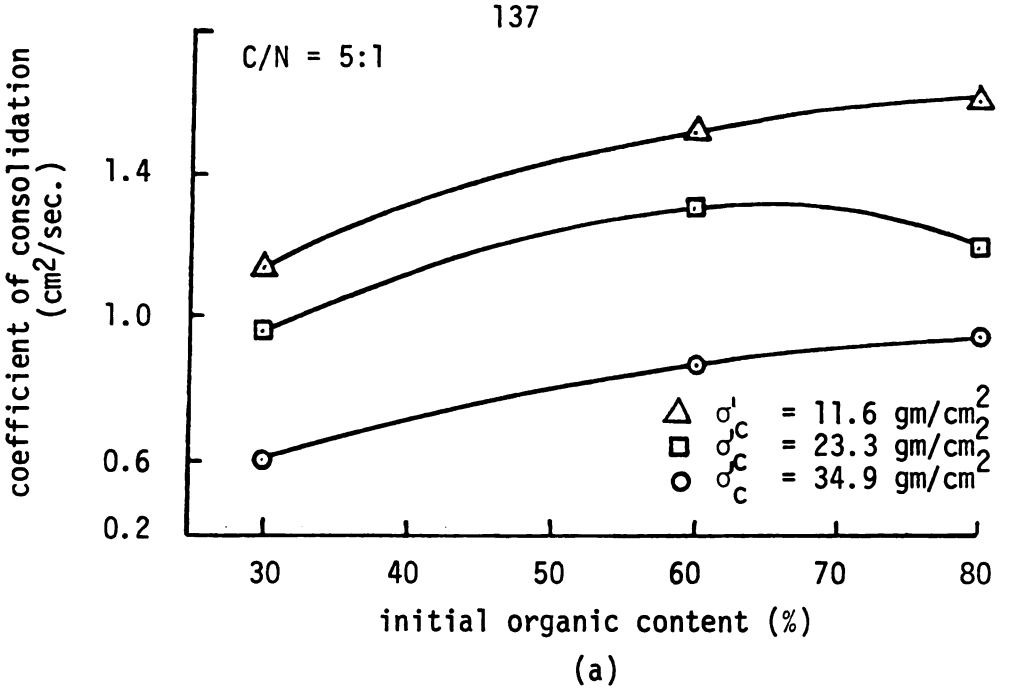


Figure 5.6.--Dehydration curves for cellulose, Kaolinite, and montmorillonite. (a) one hour duration. (b) twelve hours duration.



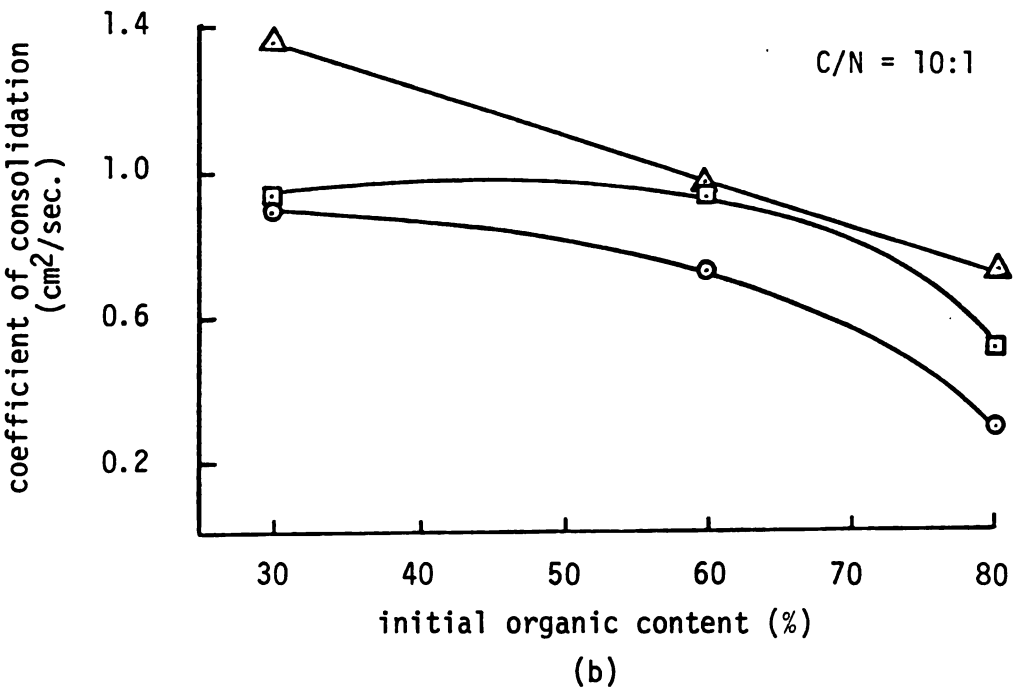
(b)

Figure 5.6.--Continued.



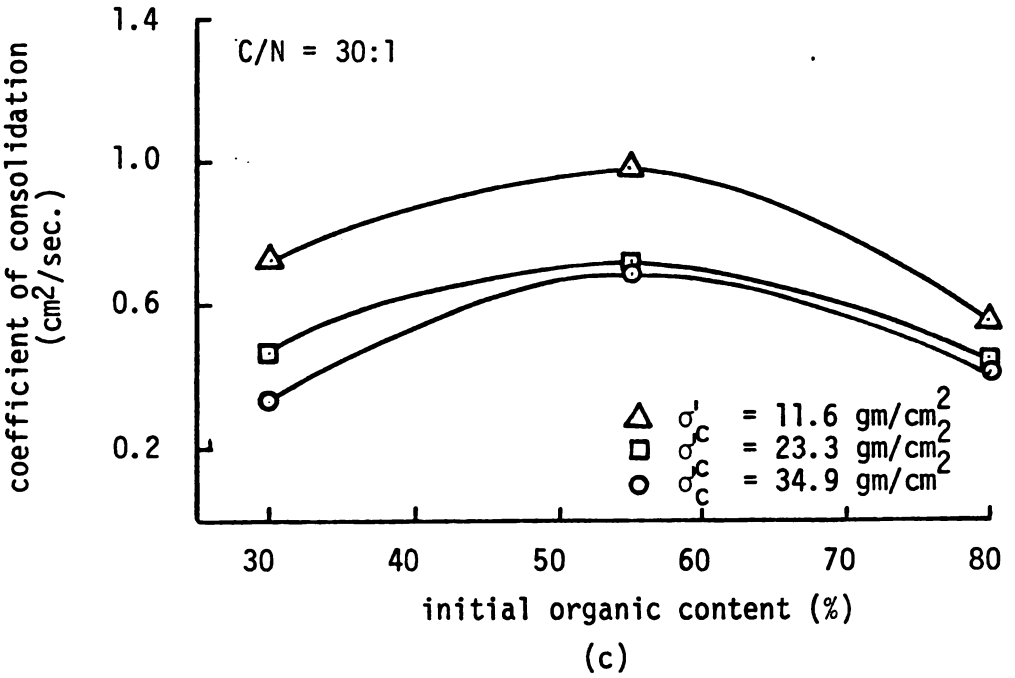
(a)

Figure 5.7.--Coefficient of consolidation versus initial organic content, aerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N). (b) 10:1 C/N ratio. (c) 30:1 C/N ratio. (d) 50:1 C/N ratio.



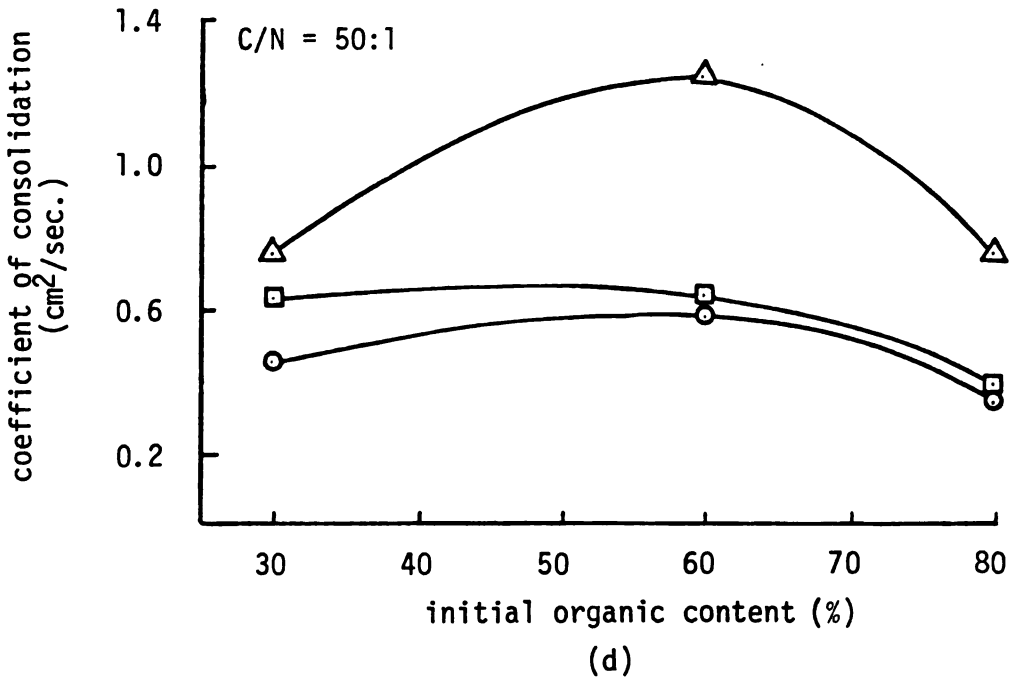
(b)

Figure 5.7.--Continued.



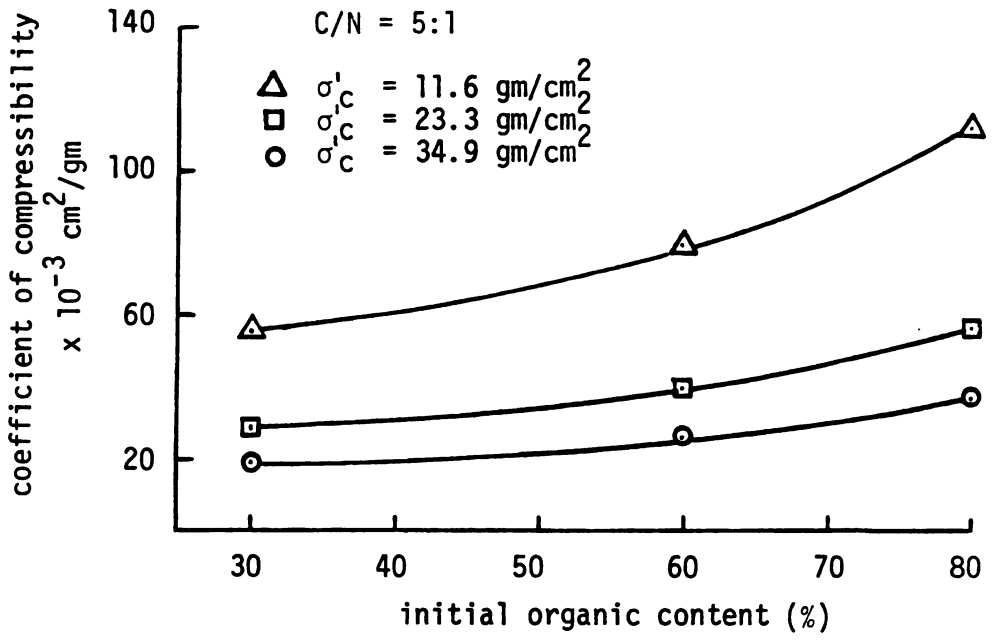
(c)

Figure 5.7.--Continued



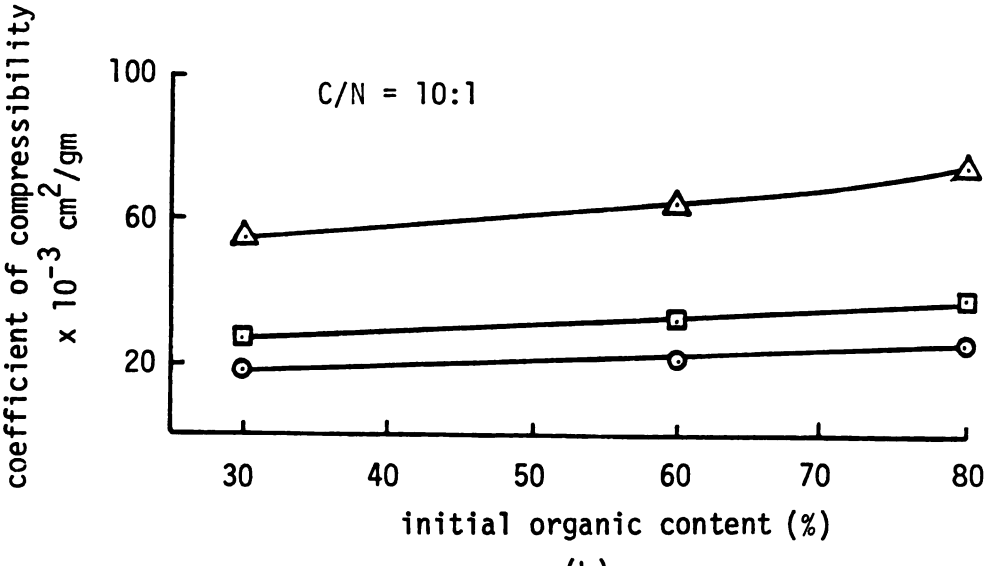
(d)

Figure 5.7.--Continued.



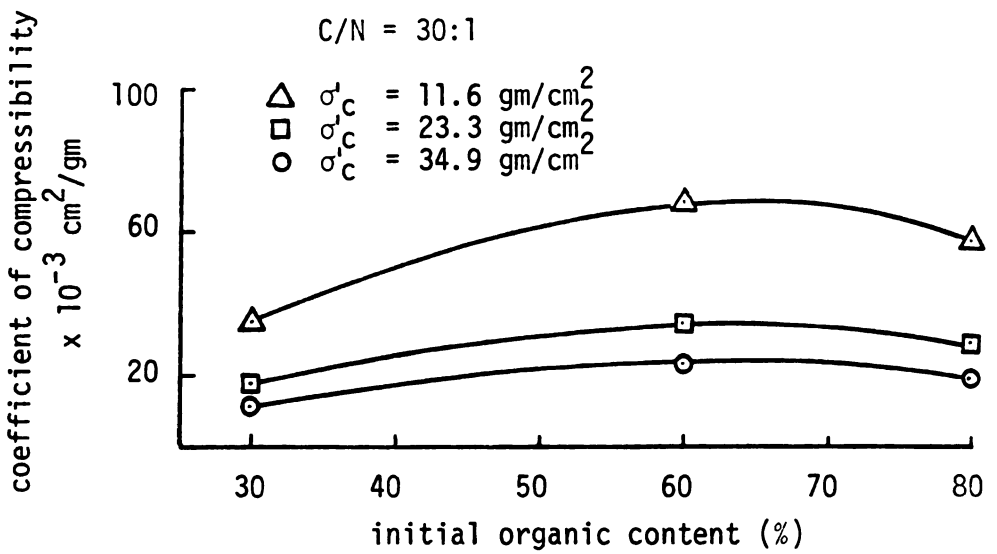
(a)

Figure 5.8.--Coefficient of compressibility versus initial organic content, aerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N). (b) 10:1 C/N ratio. (c) 30:1 C/N ratio. (d) 50:1 C/N ratio.



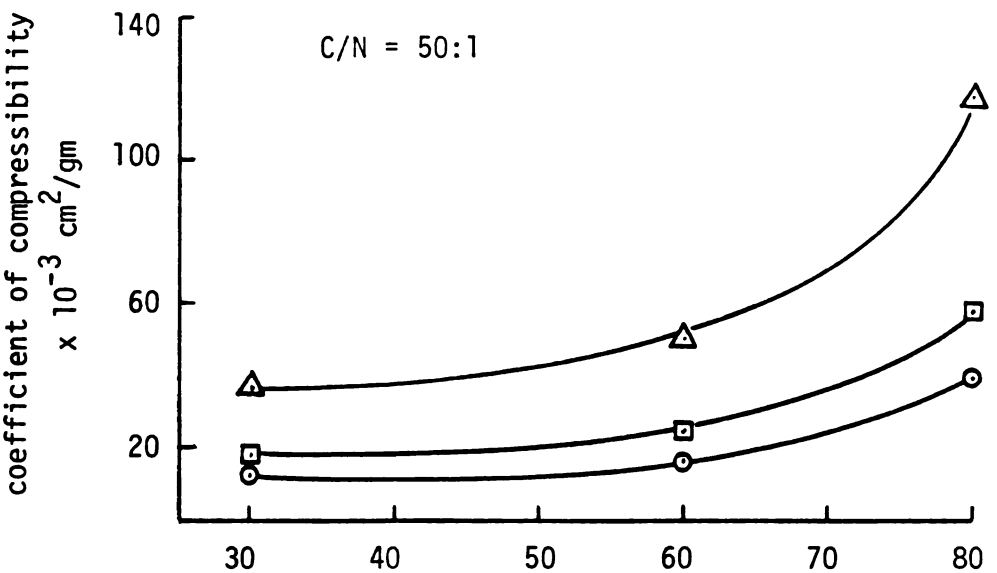
(b)

Figure 5.8.--Continued.



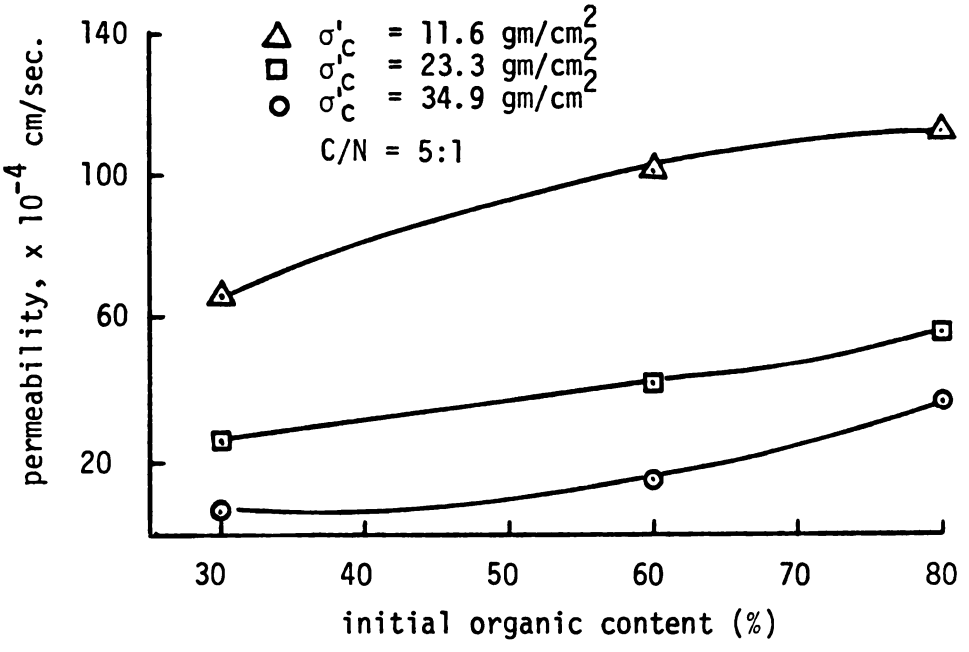
(c)

Figure 5.8.--Continued.



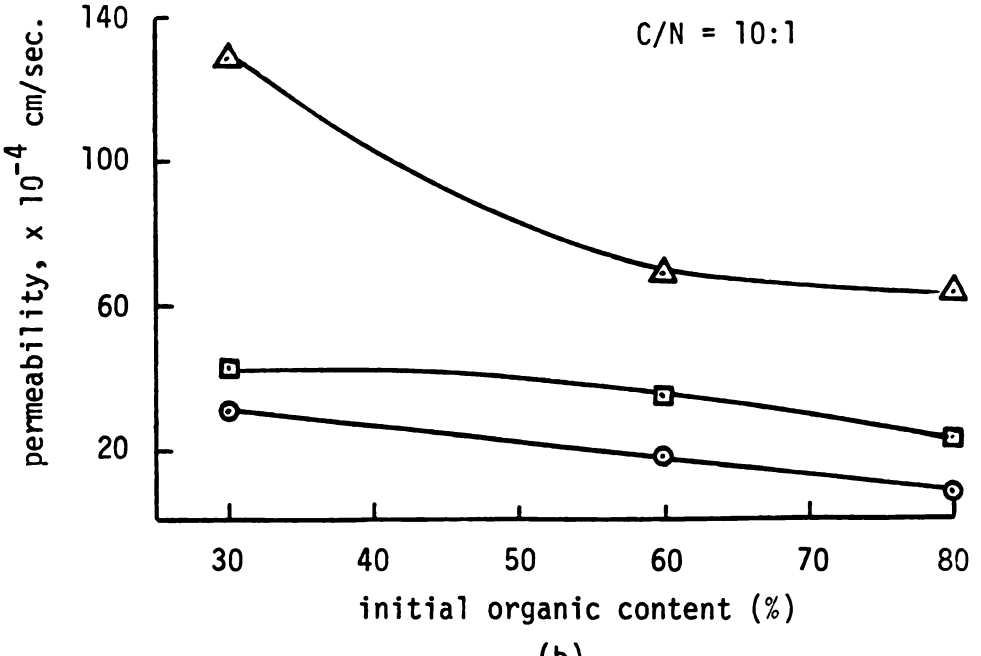
(d)

Figure 5.8.--Continued.



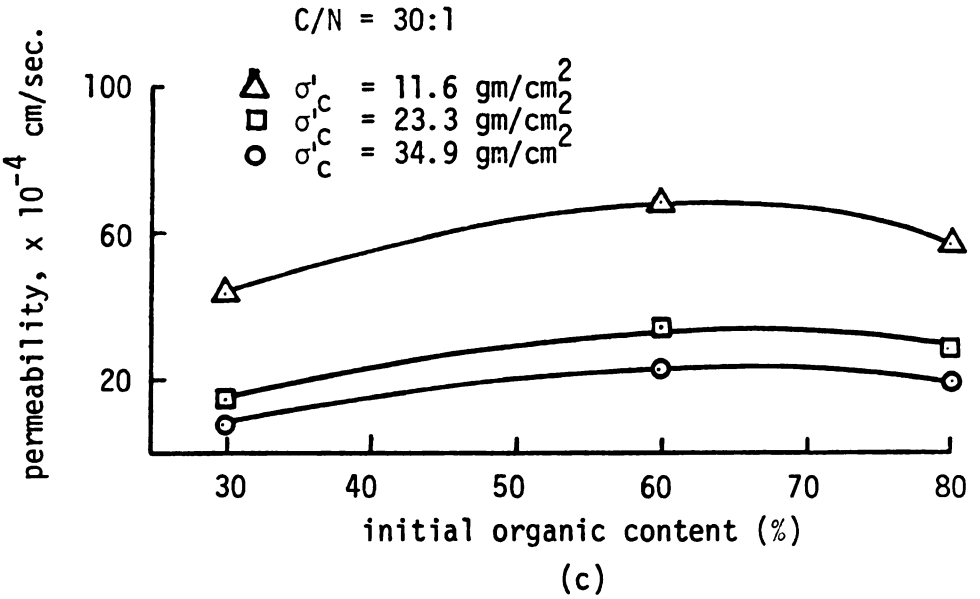
(a)

Figure 5.9.--Coefficient of permeability versus initial organic content, aerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N). (b) 10:1 C/N ratio. (c) 30:1 C/N ratio. (d) 50:1 C/N ratio.



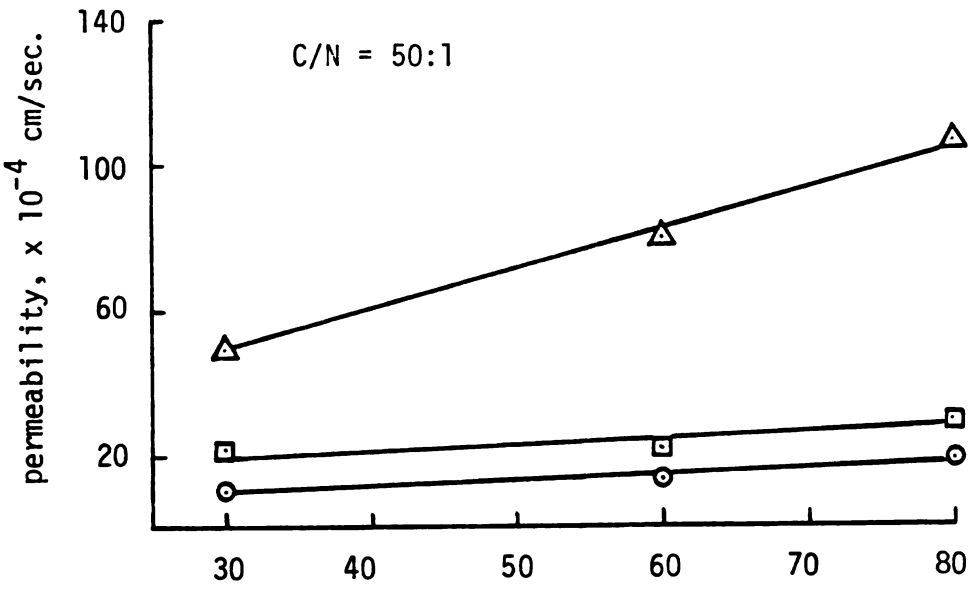
(b)

Figure 5.9.--Continued.



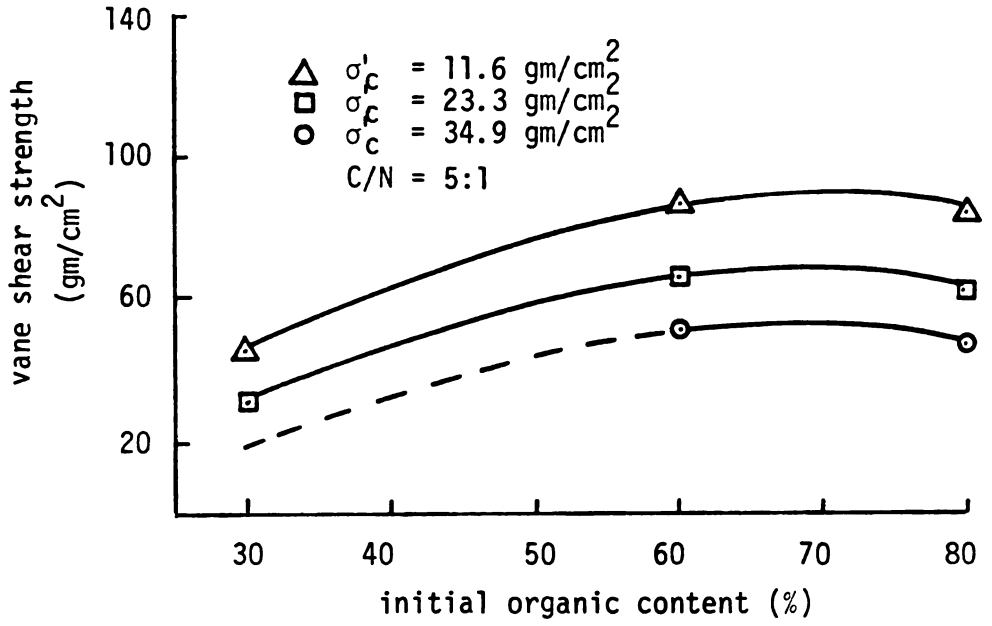
(c)

Figure 5.9.--Continued.



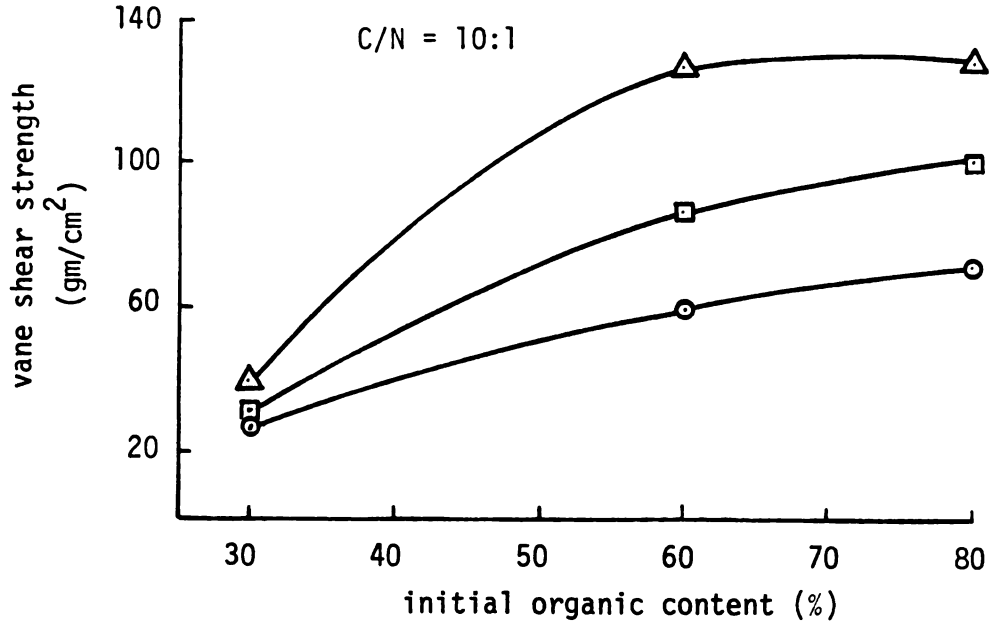
(d)

Figure 5.9.--Continued.



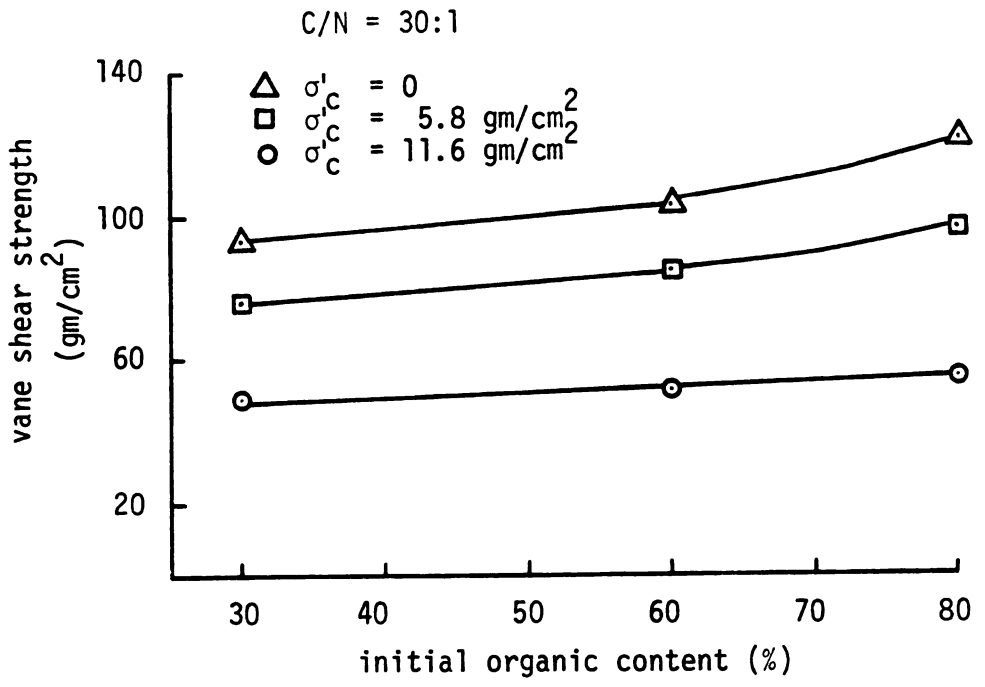
(a)

Figure 5.10.--Vane shear strength versus initial organic content, aerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N). (b) 10:1 C/N ratio. (c) 30:1 C/N ratio. (d) 50:1 C/N ratio.



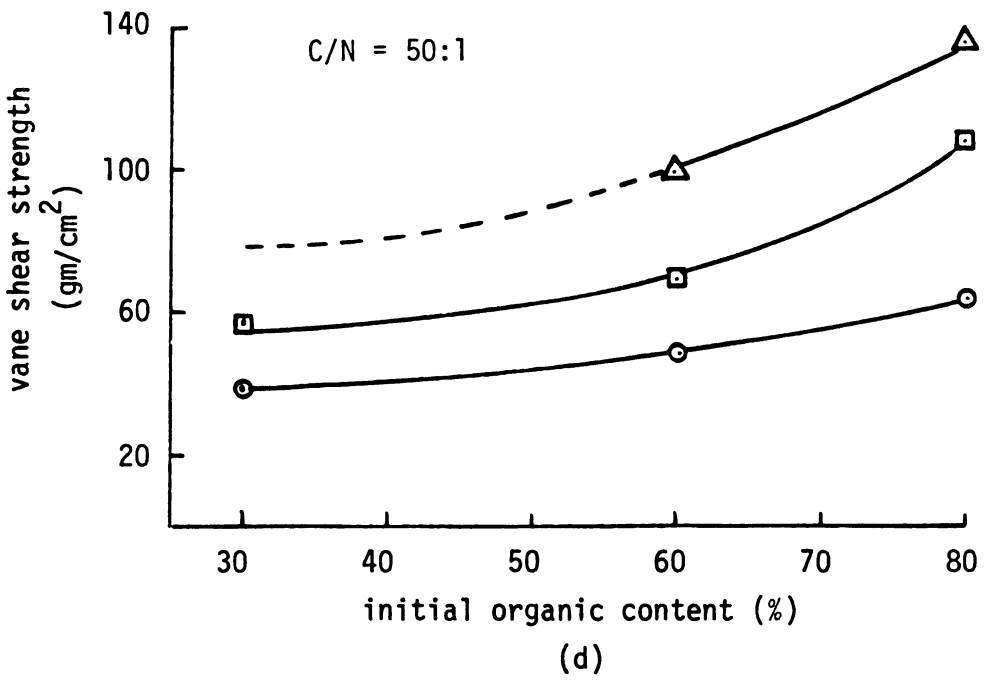
(b)

Figure 5.10.--Continued.



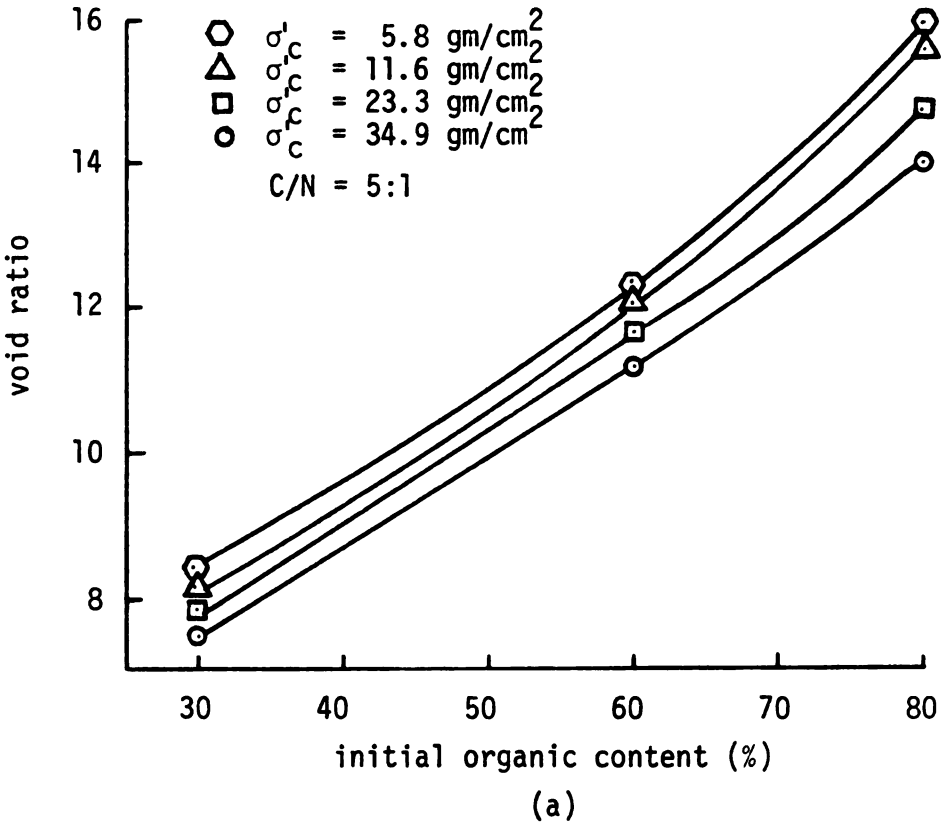
(c)

Figure 5.10.--Continued.



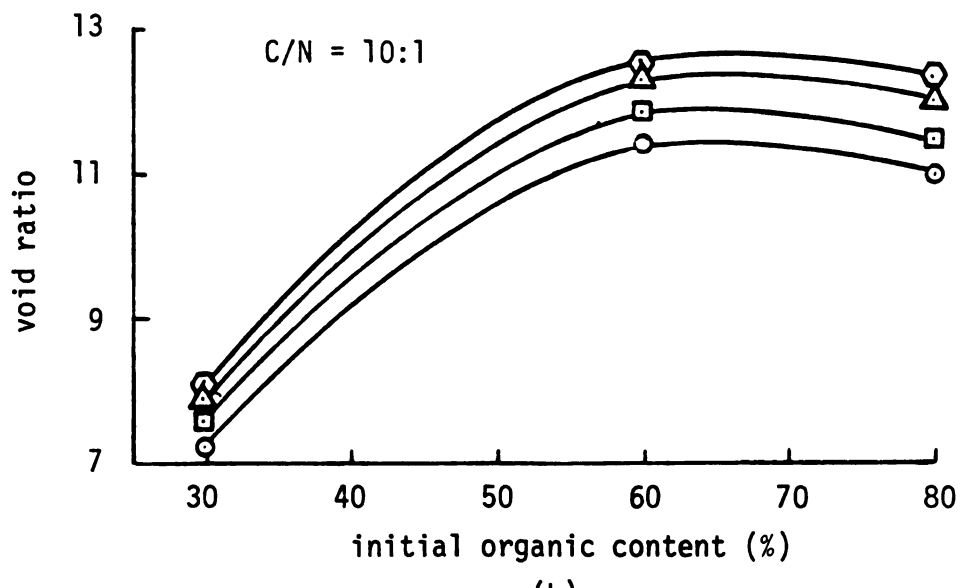
(d)

Figure 5.10.--Continued.



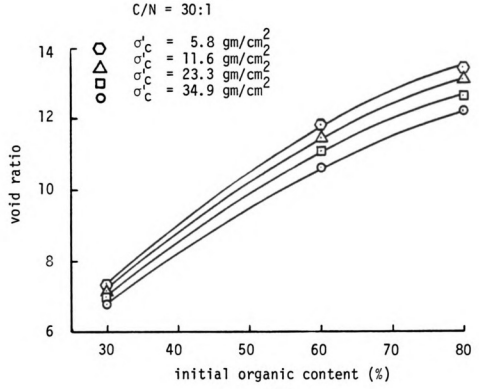
(a)

Figure 5.11.--Void ratio versus initial organic content, aerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N). (b) 10:1 C/N ratio. (c) 30:1 C/N ratio. (d) 50:1 C/N ratio.



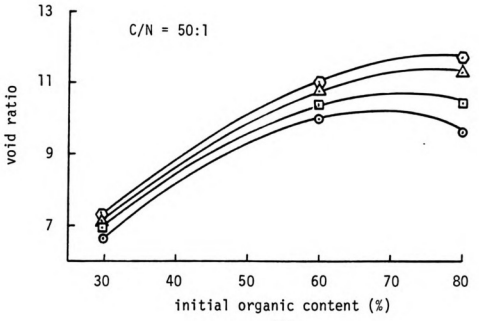
(b)

Figure 5.11.--Continued.



(c)

Figure 5.11.--Continued.



(d)

Figure 5.11.--Continued.

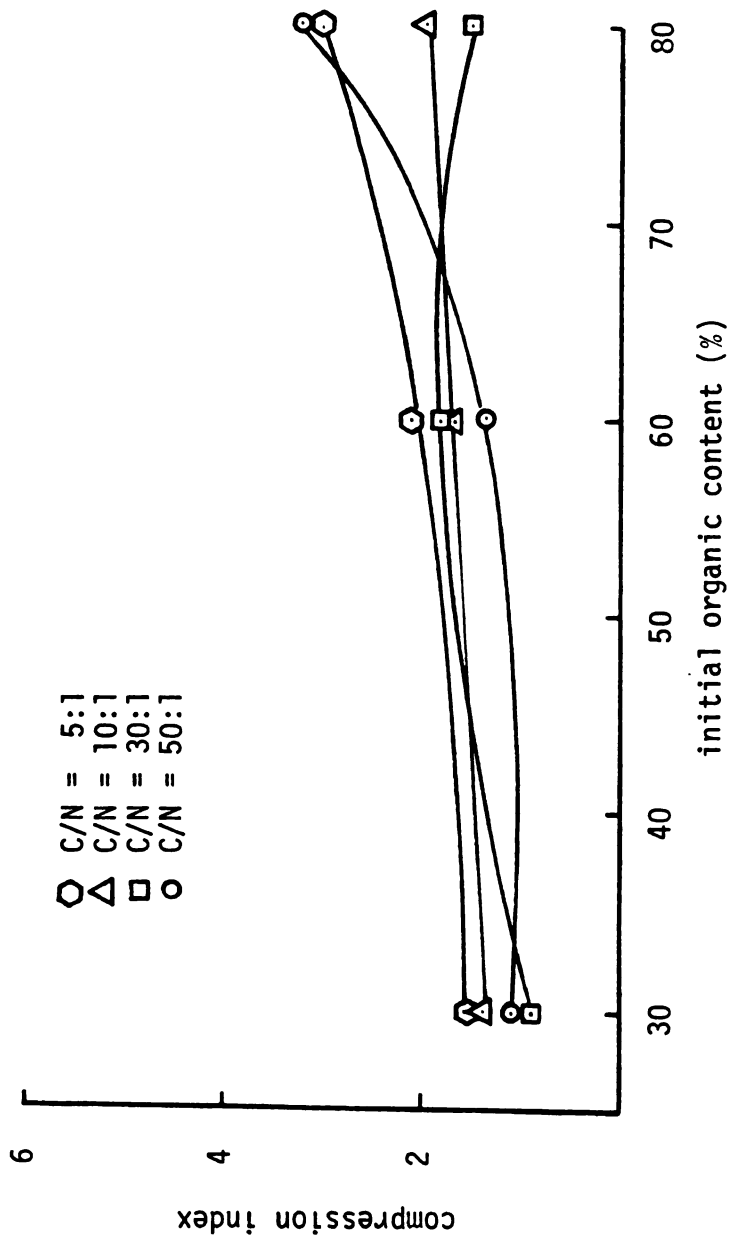


Figure 5.12.--Compression index versus organic content, aerobic conditions.

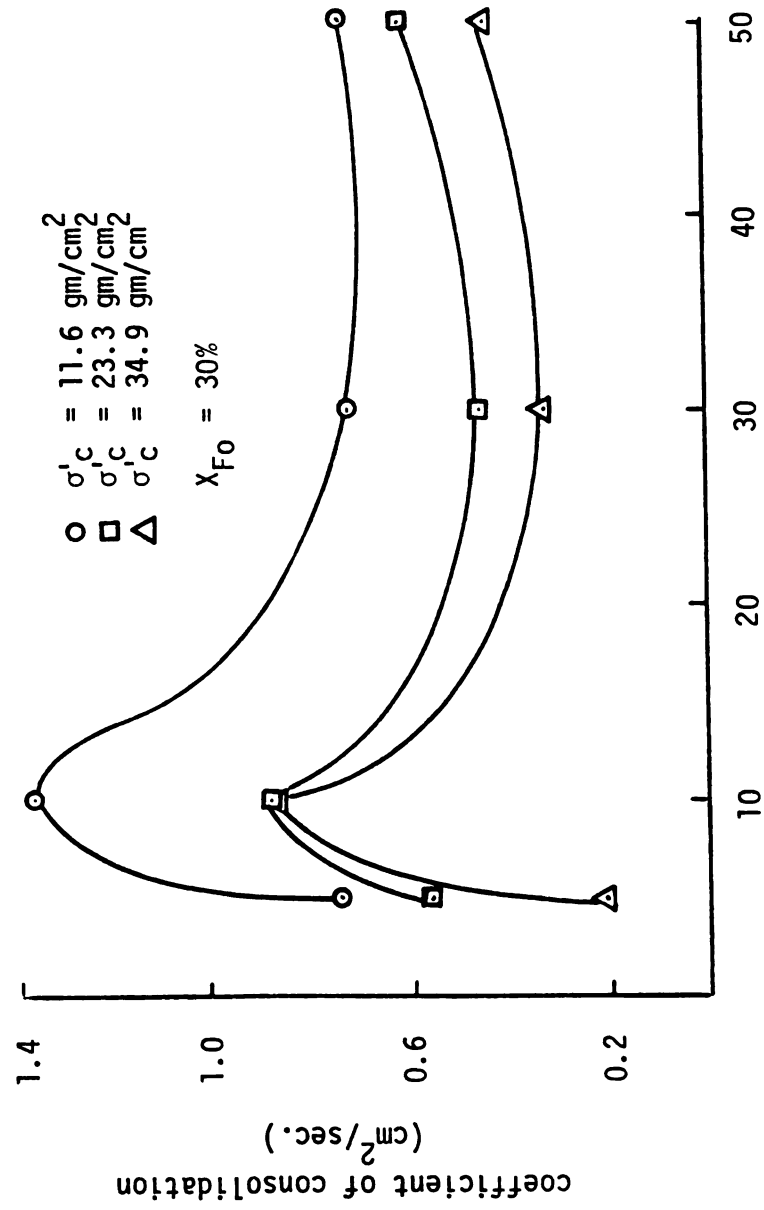
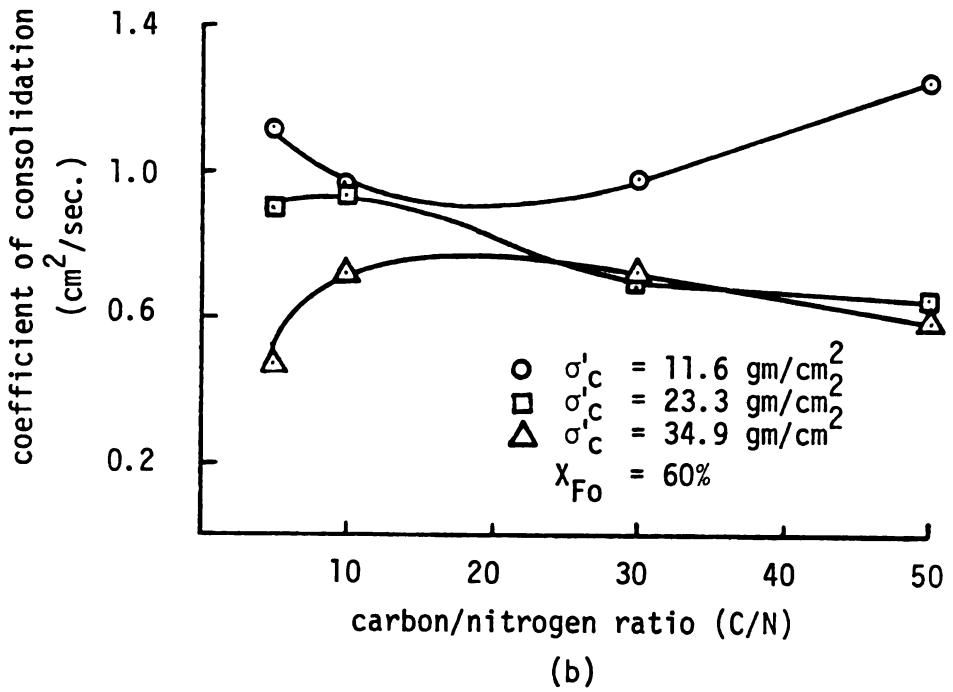
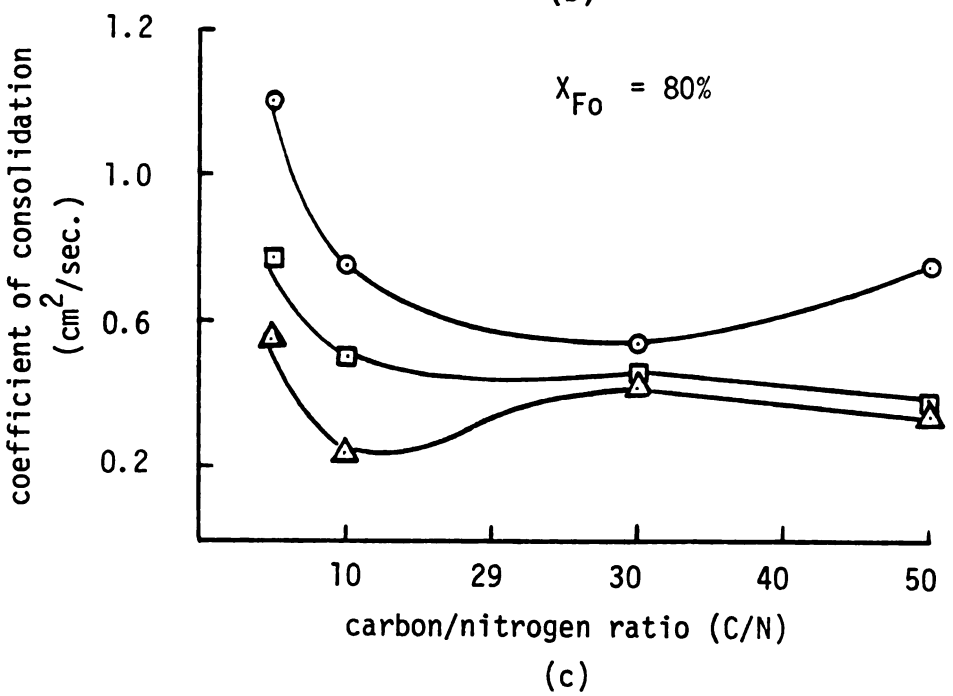


Figure 5.13.--Coefficient of consolidation versus carbon/nitrogen ratio, aerobic conditions. (a) 30% by weight organic content X_{Fo}. (b) 60% X_{Fo}. (c) 80% X_{Fo}.



(b)



(c)

Figure 5.13.--Continued.

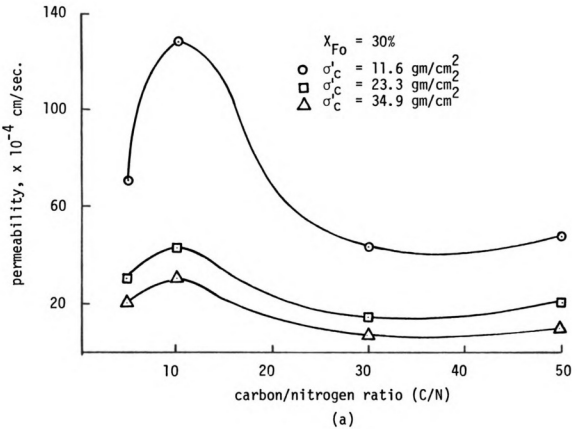
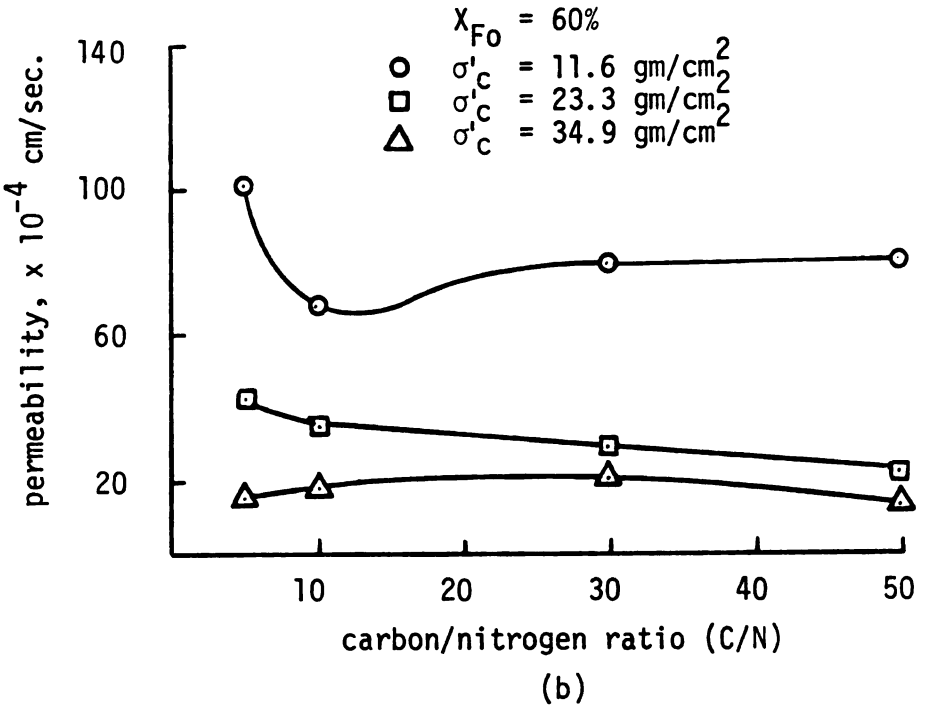


Figure 5.14.--Coefficient of permeability versus C/N ratio, aerobic conditions. (a) 30% by weight organic content (X_{Fo}). (b) 60%, X_{Fo}. (c) 80%, X_{Fo}.



(b)

Figure 5.14.--Continued.

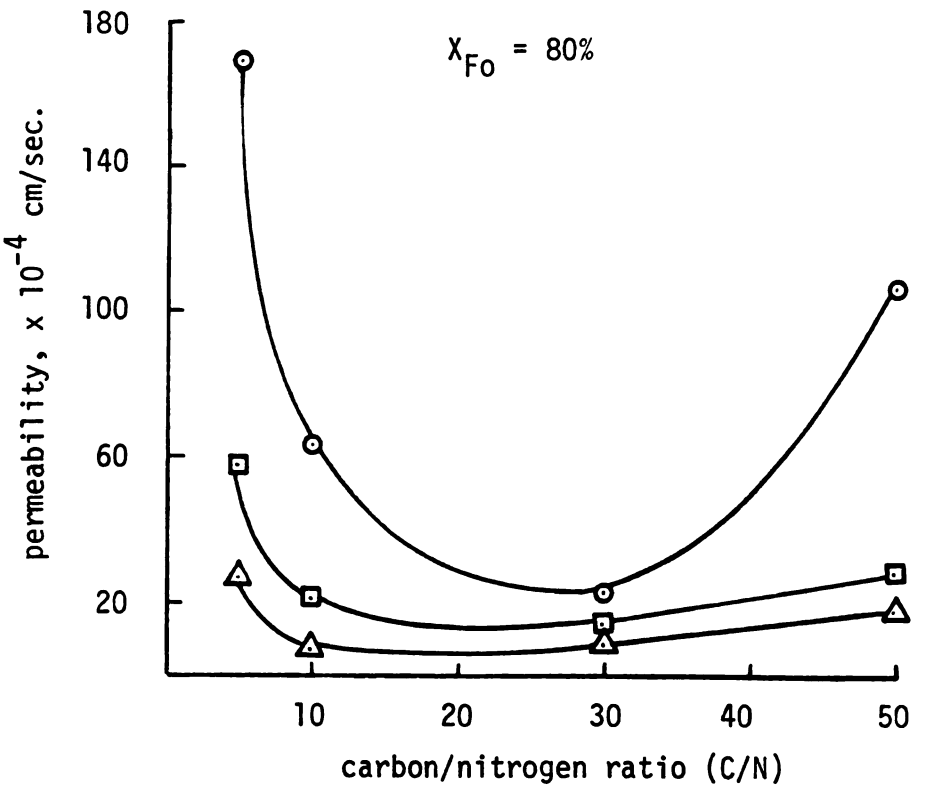


Figure 5.14.--Continued.

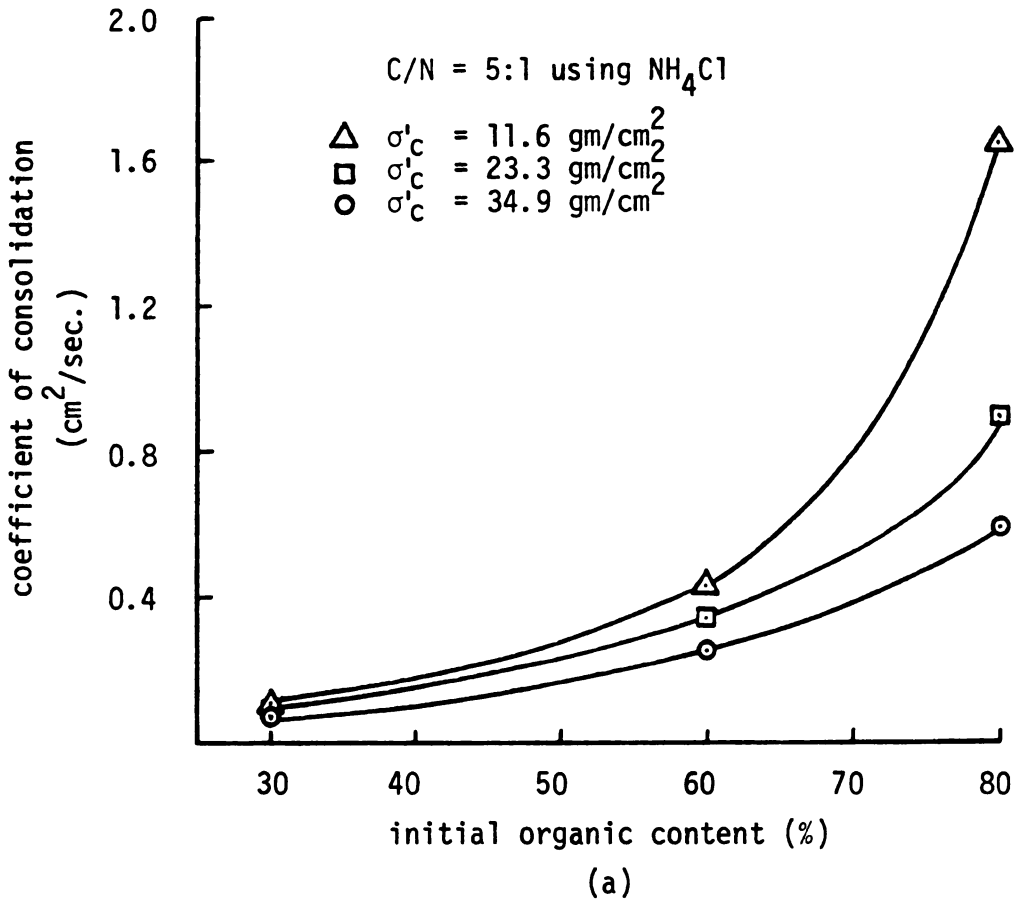
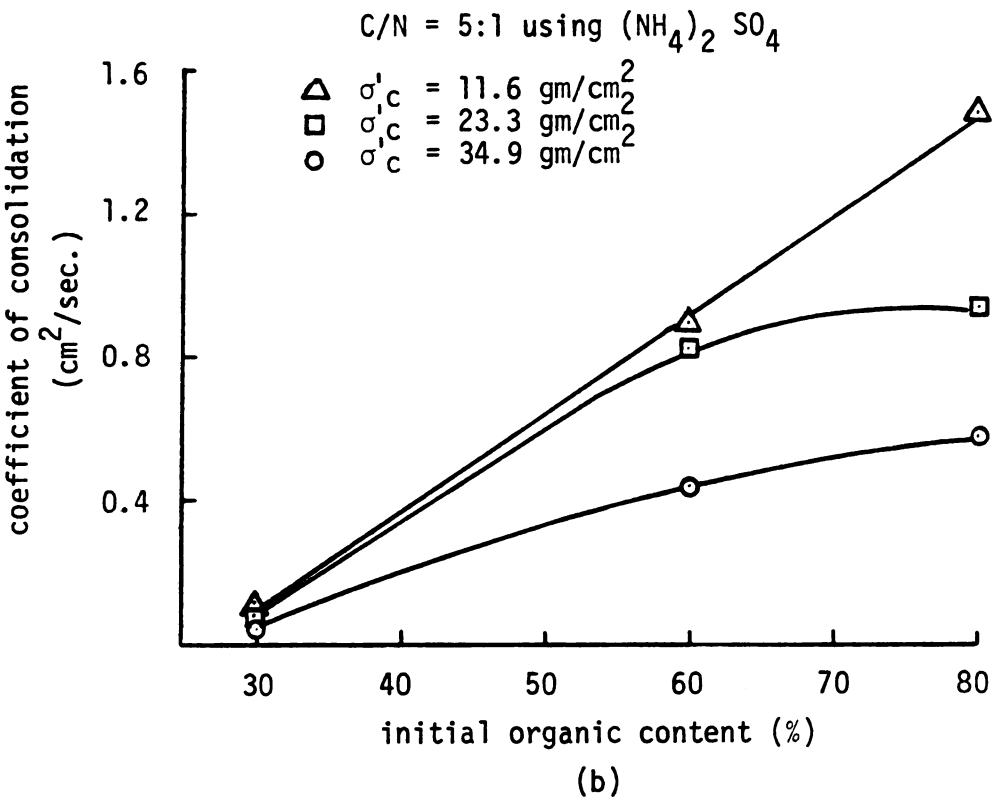
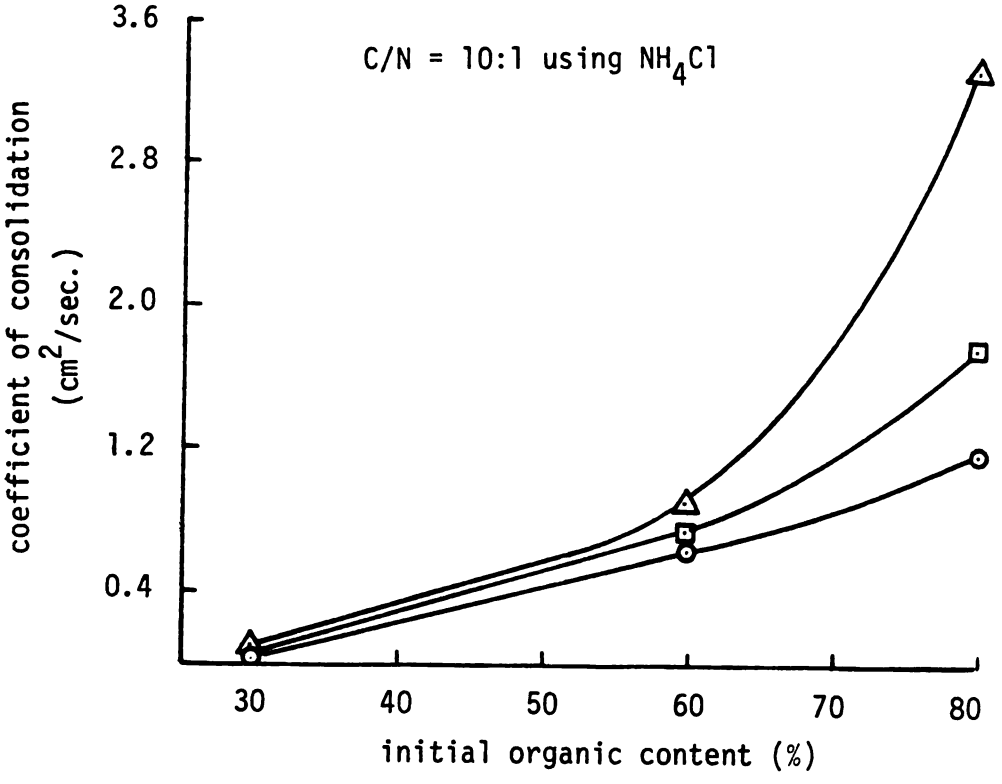


Figure 5.15.--Coefficient of consolidation versus initial organic content, anaerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N), using NH_4Cl. (b) 5:1 C/N ratio, using $(NH_4)_2SO_4$. (c) 10:1 C/N ratio, using NH_4Cl. (d) 10:1 C/N ratio, using $(NH_4)_2\ SO_4$. (e) 30:1 C/N ratio, using NH_4Cl. (f) 50:1 C/N ratio, using NH_4Cl. (g) 200:1 C/N ratio, using NH_4Cl. (h) ∞:1 C/N ratio.

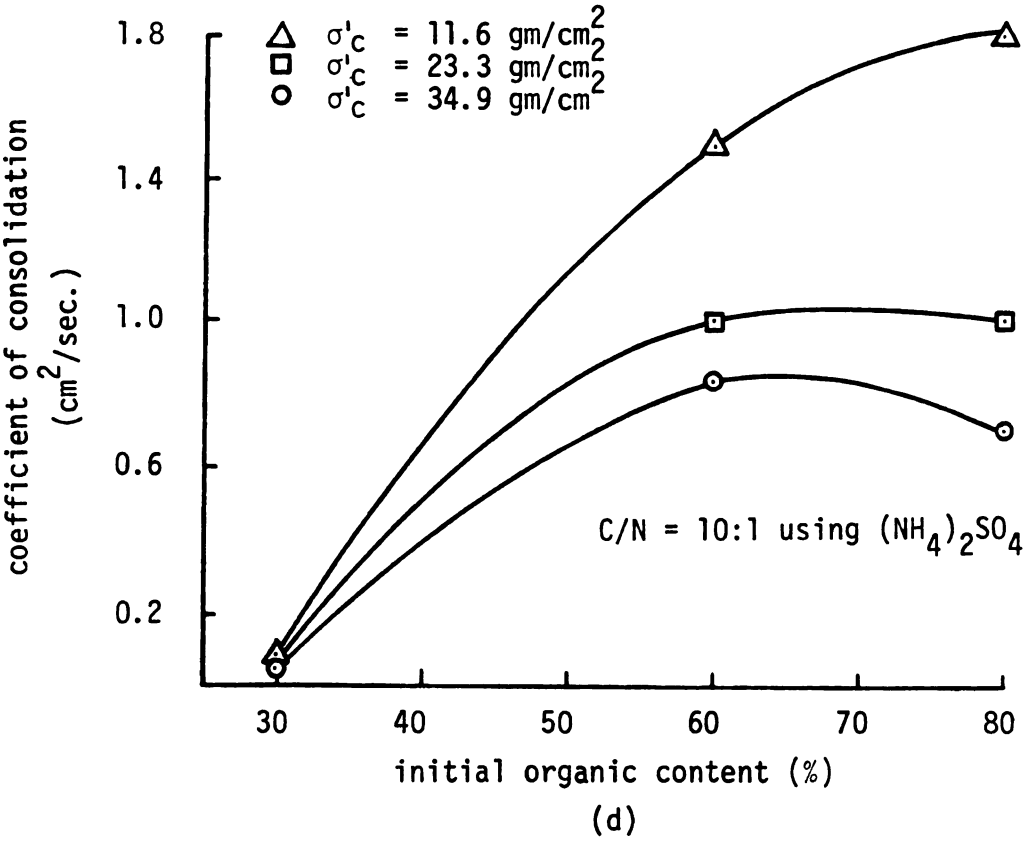


(b)

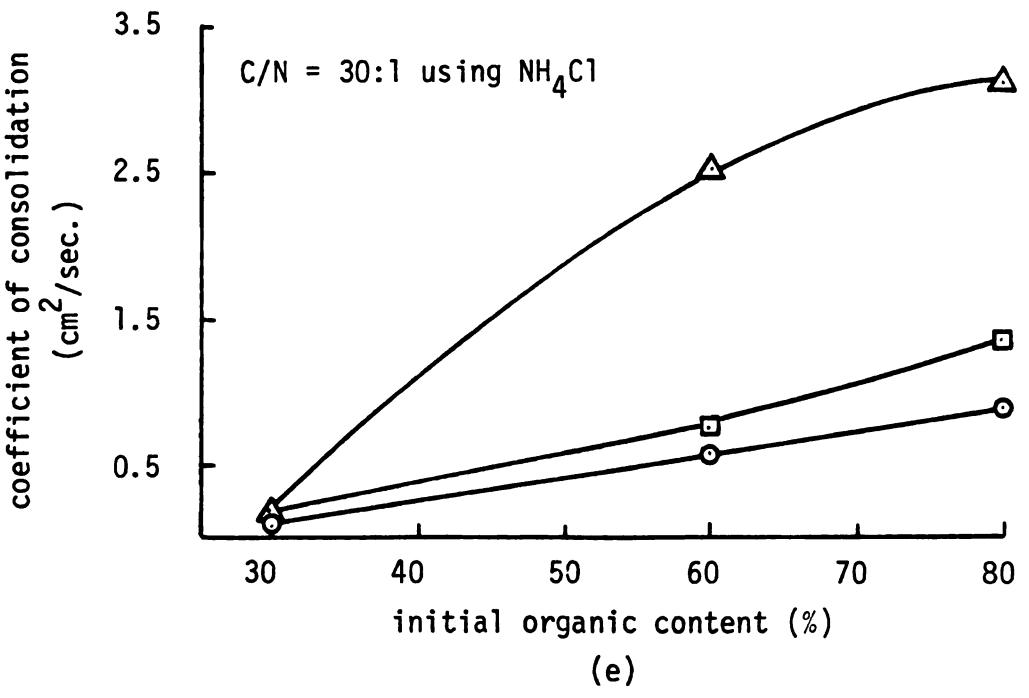


(c)

Figure 5.15.--Continued.

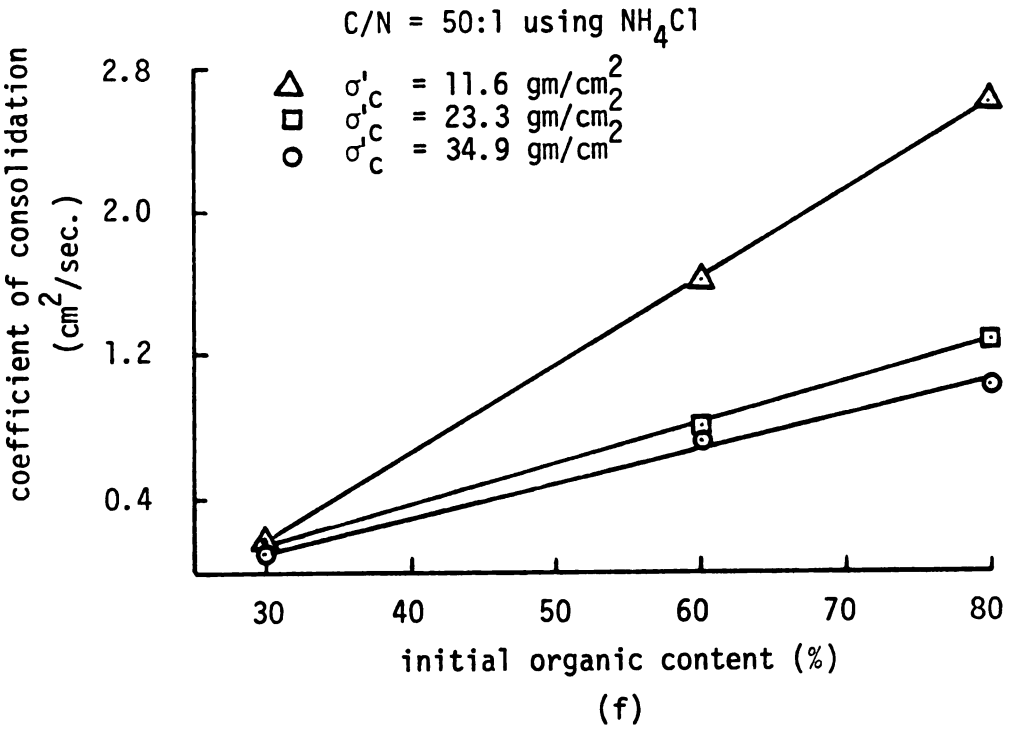


(d)

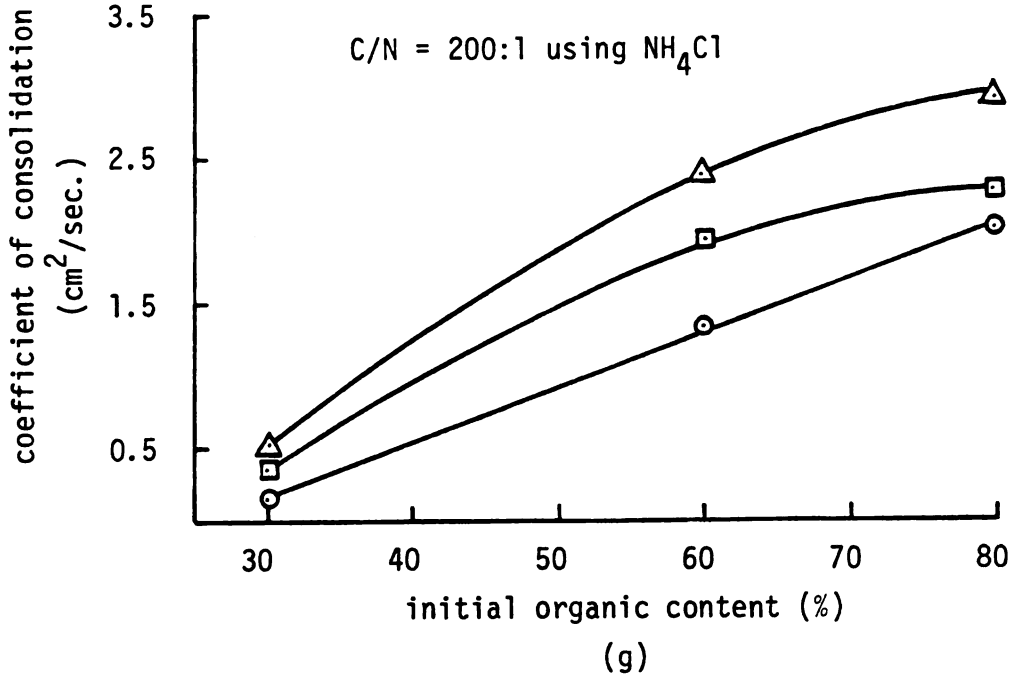


(e)

Figure 5.15.--Continued.



(f)



(g)

Figure 5.15.--Continued.

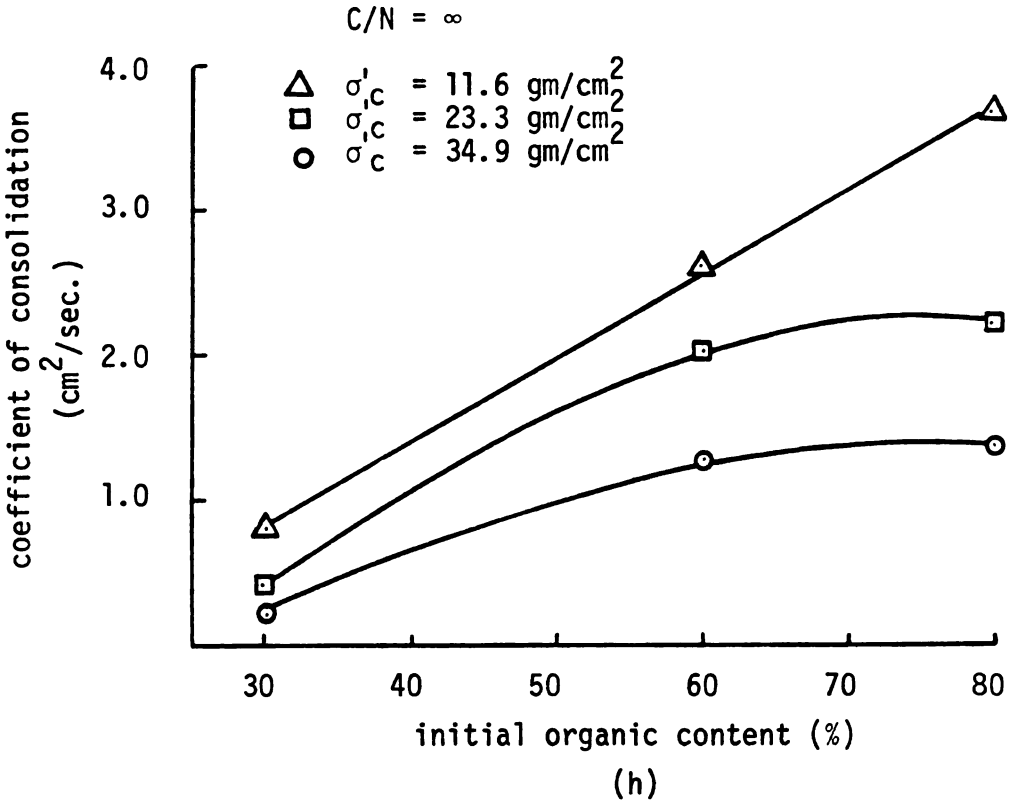


Figure 5.15.--Continued.

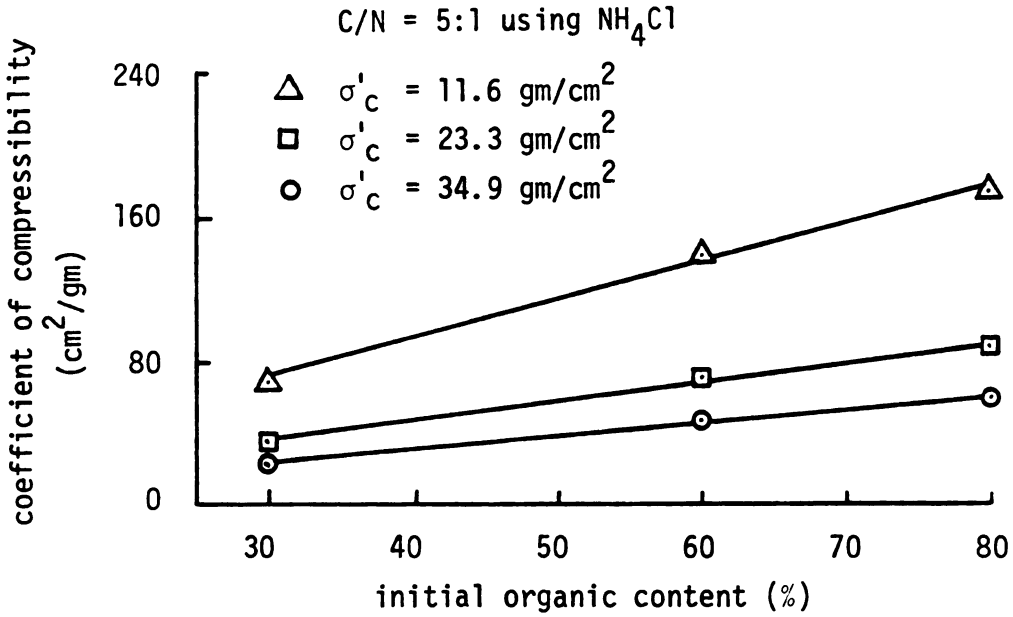
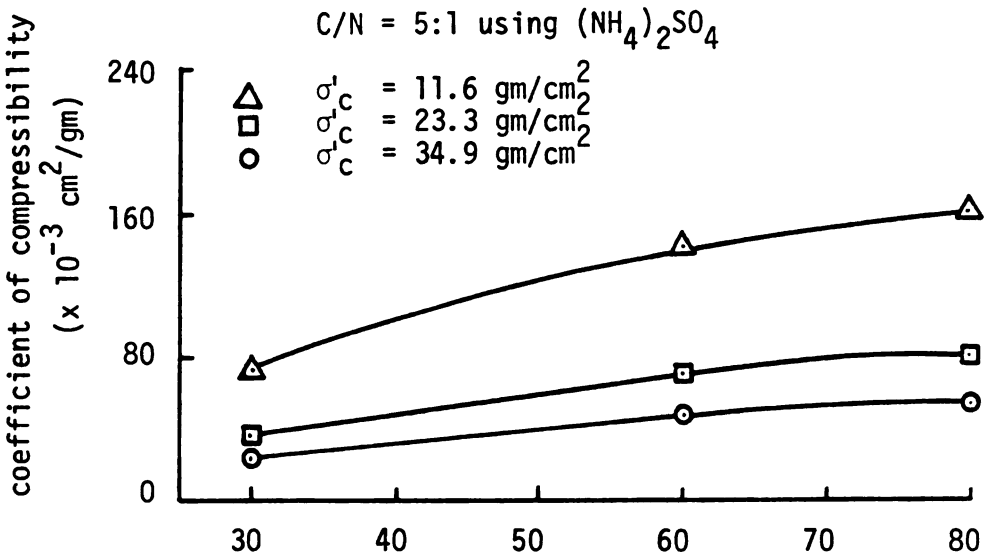
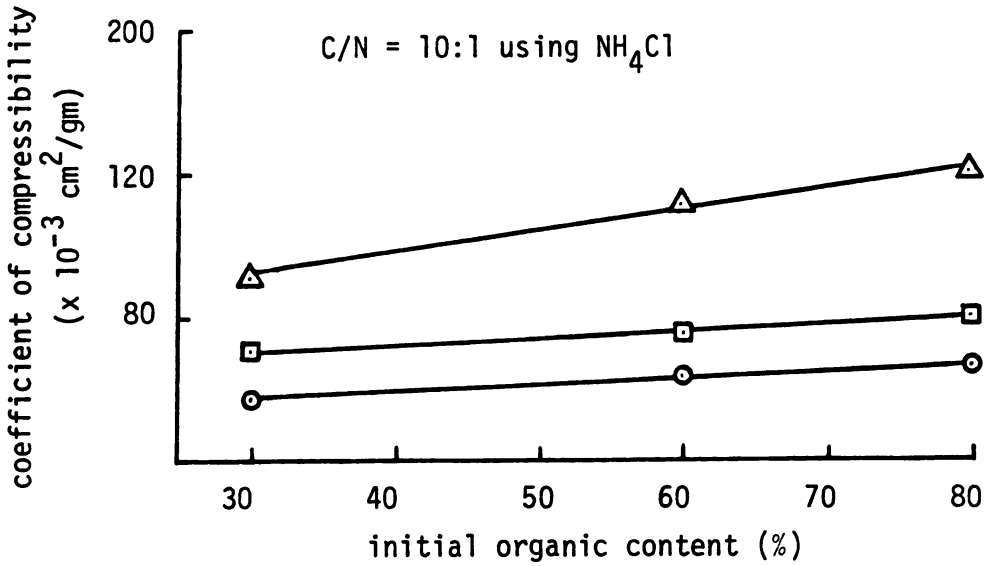


Figure 5.16.--Coefficient of compressibility versus initial organic content, anaerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N), using NH_4Cl. (b) 5:1 C/N ratio, using $(NH_4)_2SO_4$. (c) 10:1 C/N ratio, using NH_4Cl. (d) 10:1 C/N ratio, using $(NH_4)_2SO_4$. (e) 30:1 C/N ratio, using NH_4Cl. (f) 50:1 C/N ratio, using NH_4Cl. (g) 200:1 C/N ratio, using NH_4Cl. (h) ∞:1 C/N ratio.



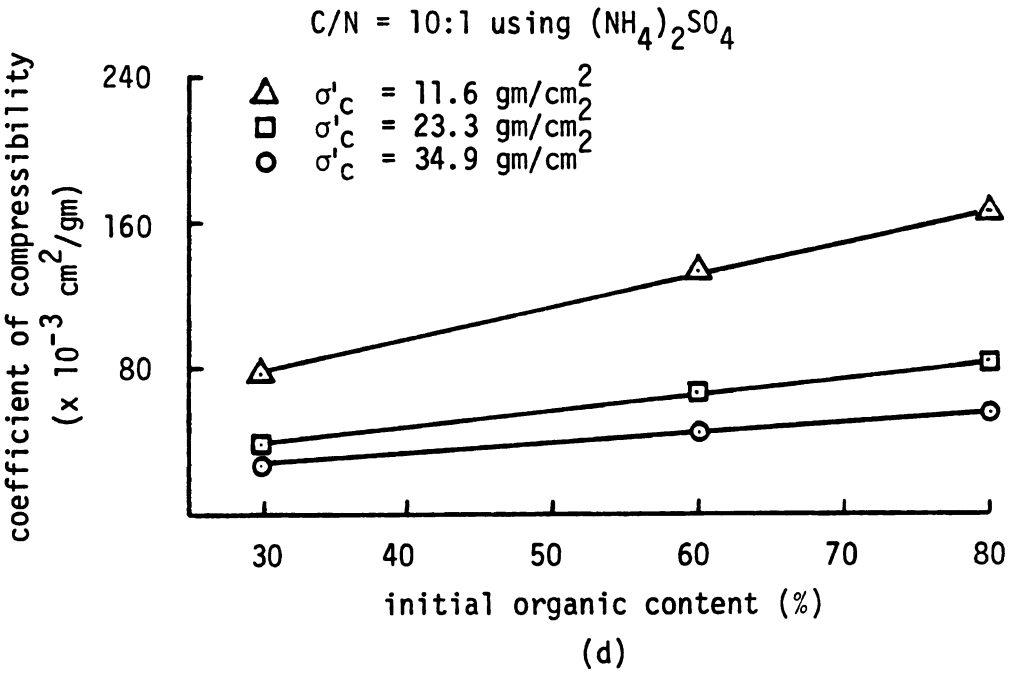
(b)

Figure 5.16.--Continued.



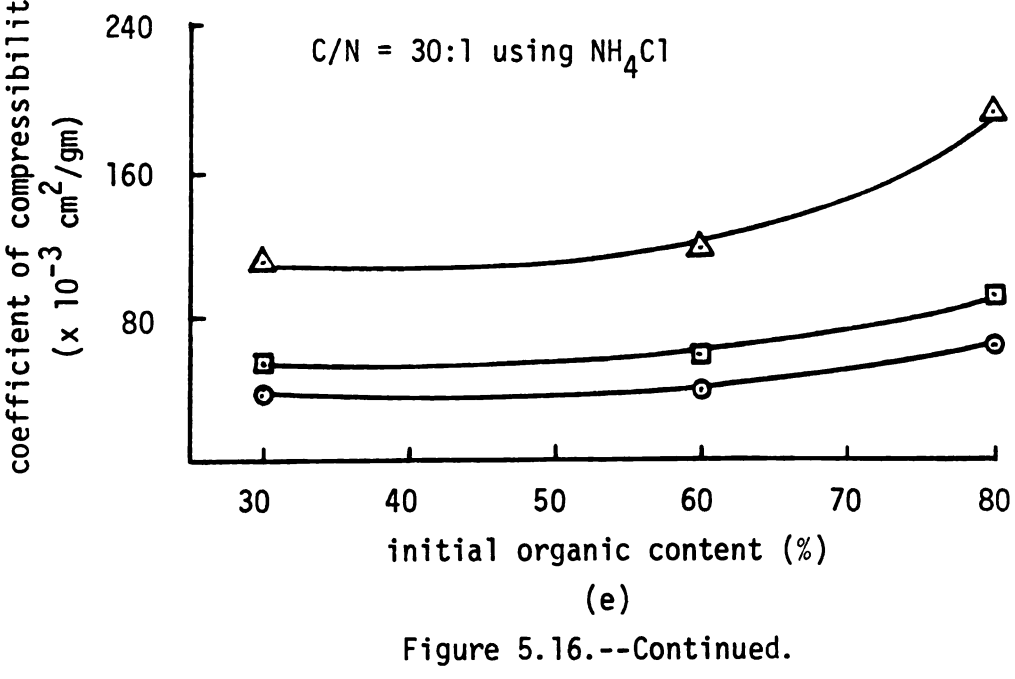
(c)

Figure 5.16.--Continued.



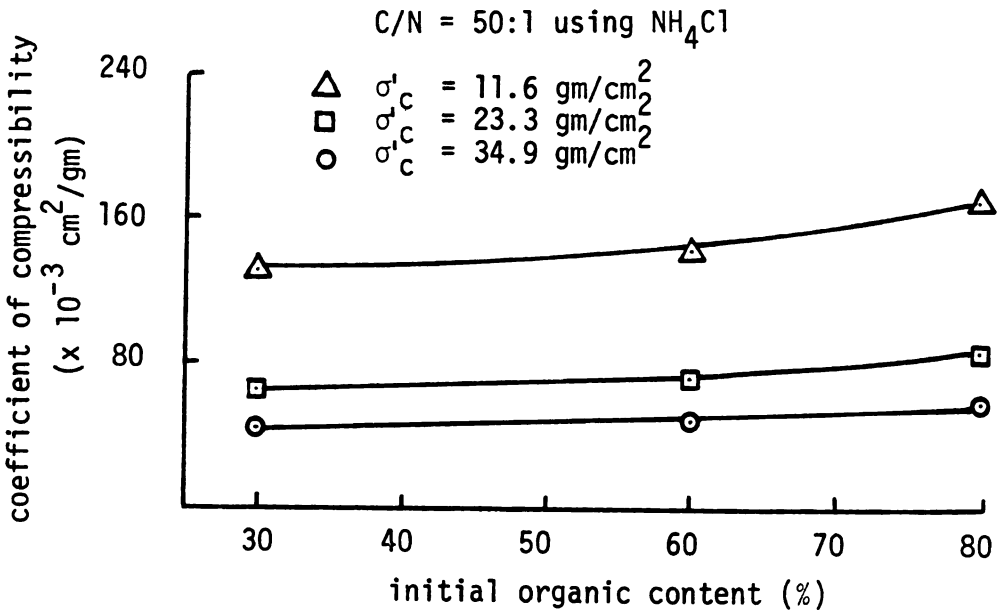
(d)

Figure 5.16.--Continued.



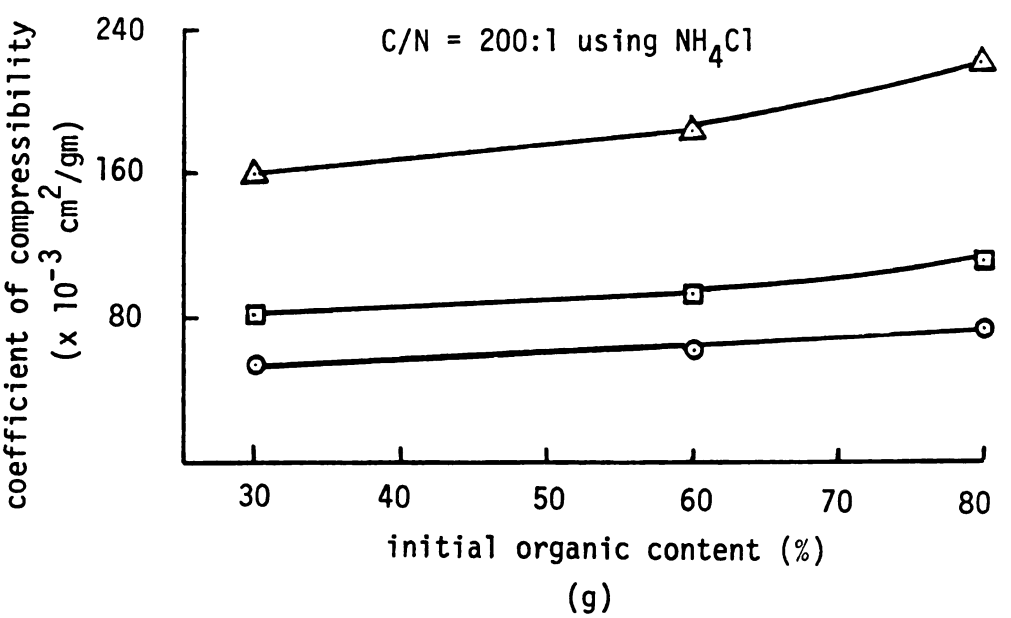
(e)

Figure 5.16.--Continued.



(f)

Figure 5.16.--Continued.



(g)

Figure 5.16.--Continued.

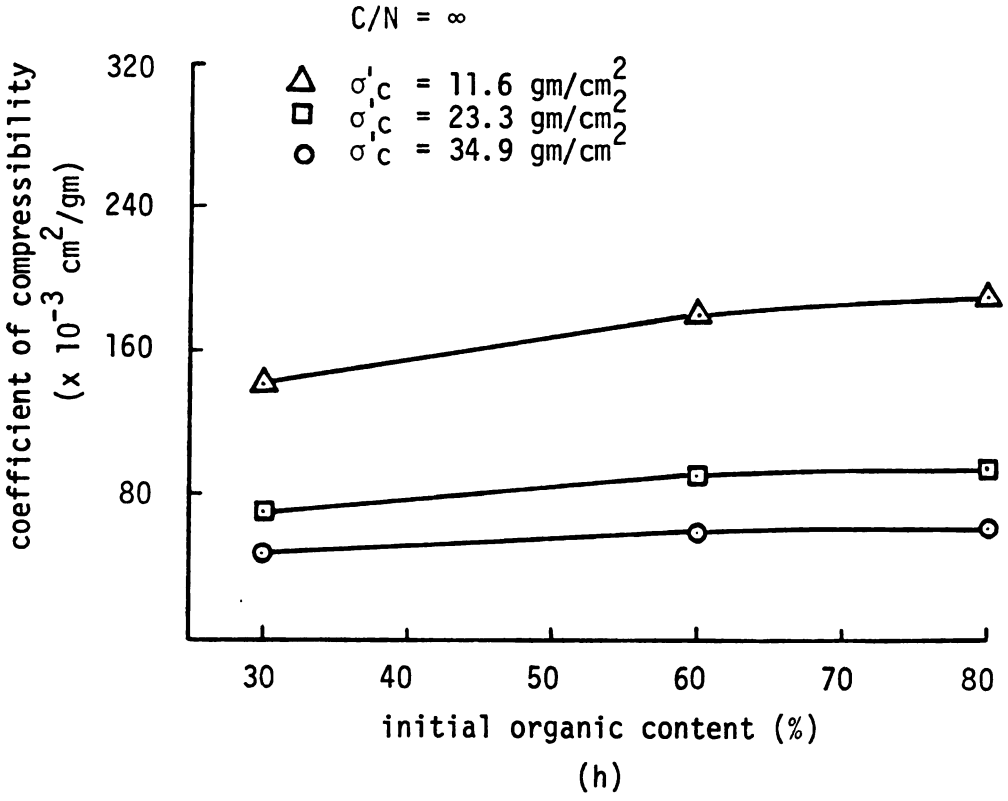


Figure 5.16.--Continued.

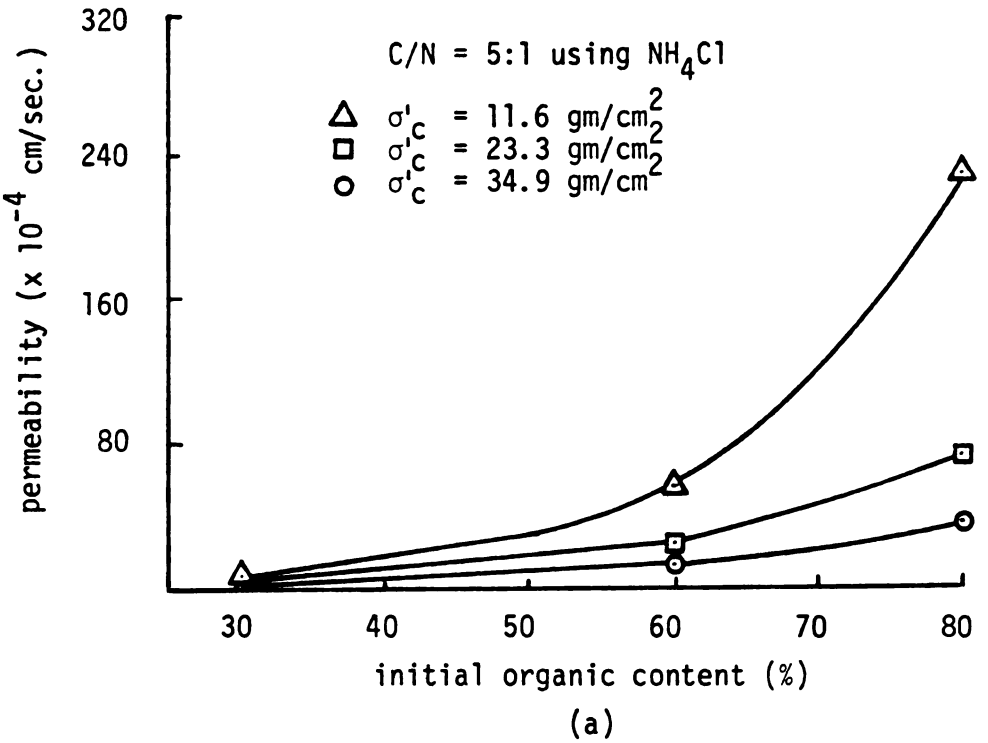
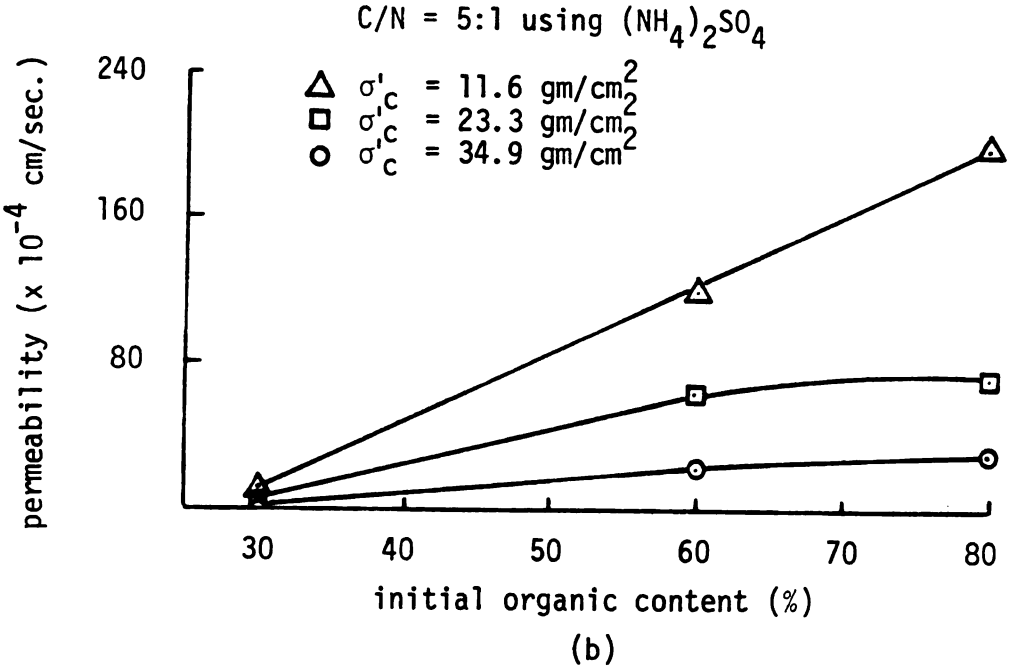
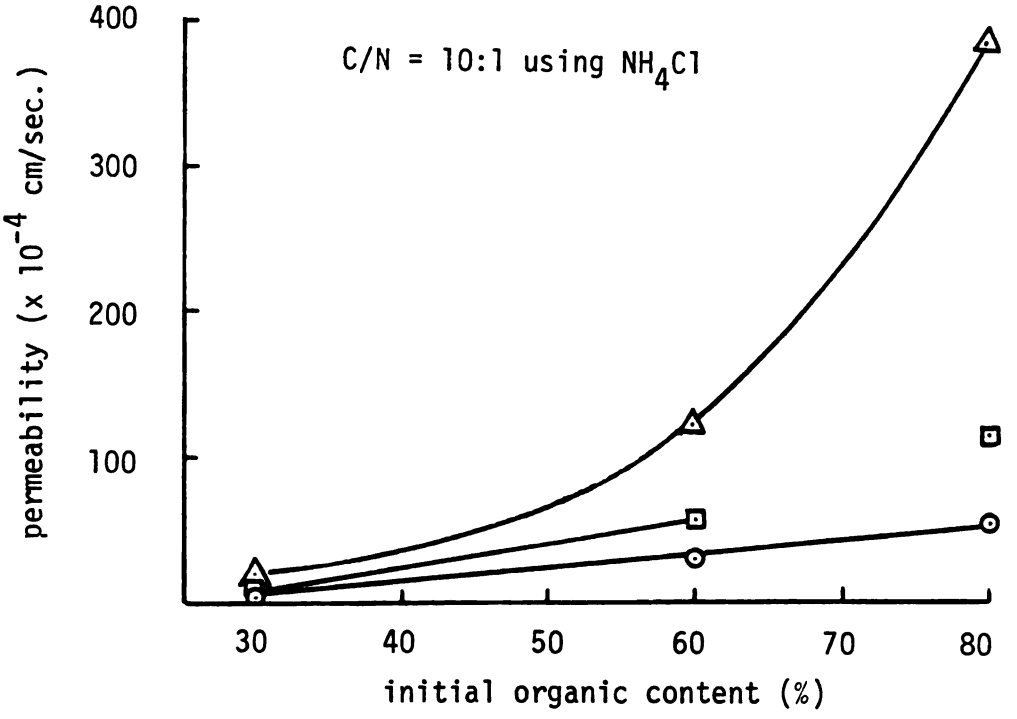


Figure 5.17.--Coefficient of permeability versus initial organic content, anaerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N), using NH_4CL. (b) 5:1 C/N ratio, using $(NH_4)_2SO_4$. (c) 10:1 C/N ratio, using NH_4Cl. (d) 10:1 C/N ratio, using $(NH_4)_2SO_4$. (e) 30:1 C/N ratio, using NH_4Cl. (f) 50:1 C/N ratio, using NH_4Cl. (g) 200:1 C/N ratio, using NH_4Cl. (h) ∞:1 C/N ratio, using NH_4Cl.



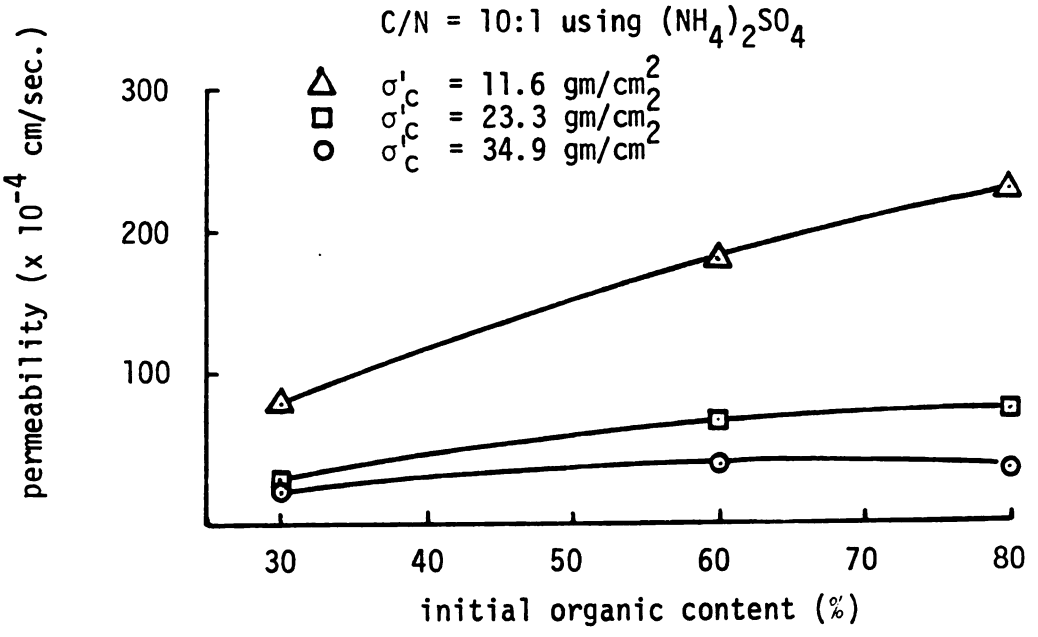
(b)

Figure 5.17.--Continued.



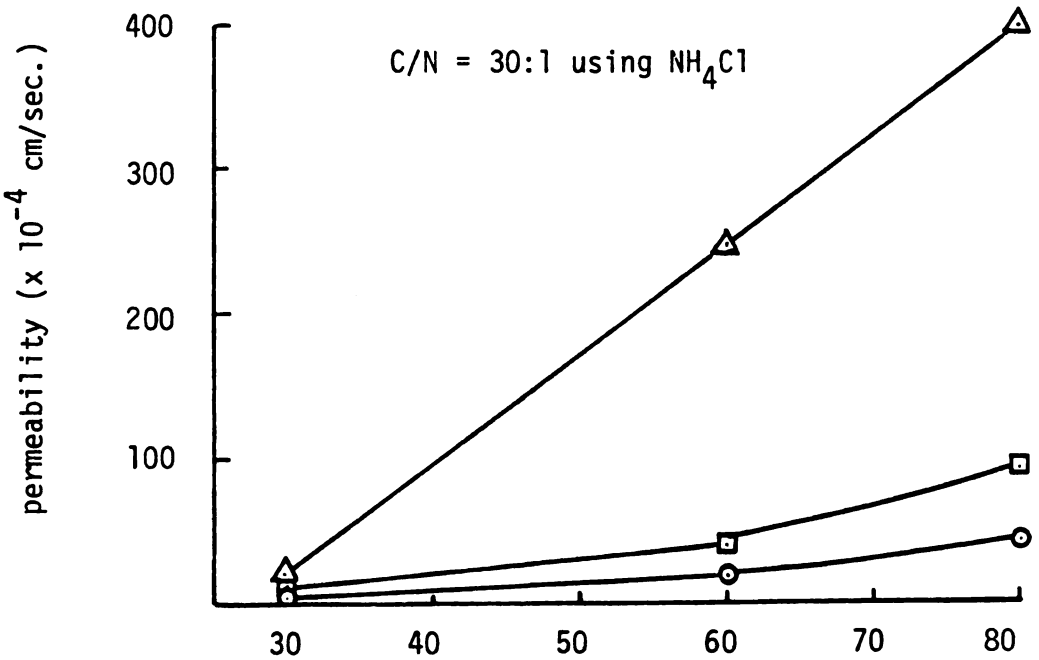
(c)

Figure 5.17.--Continued.



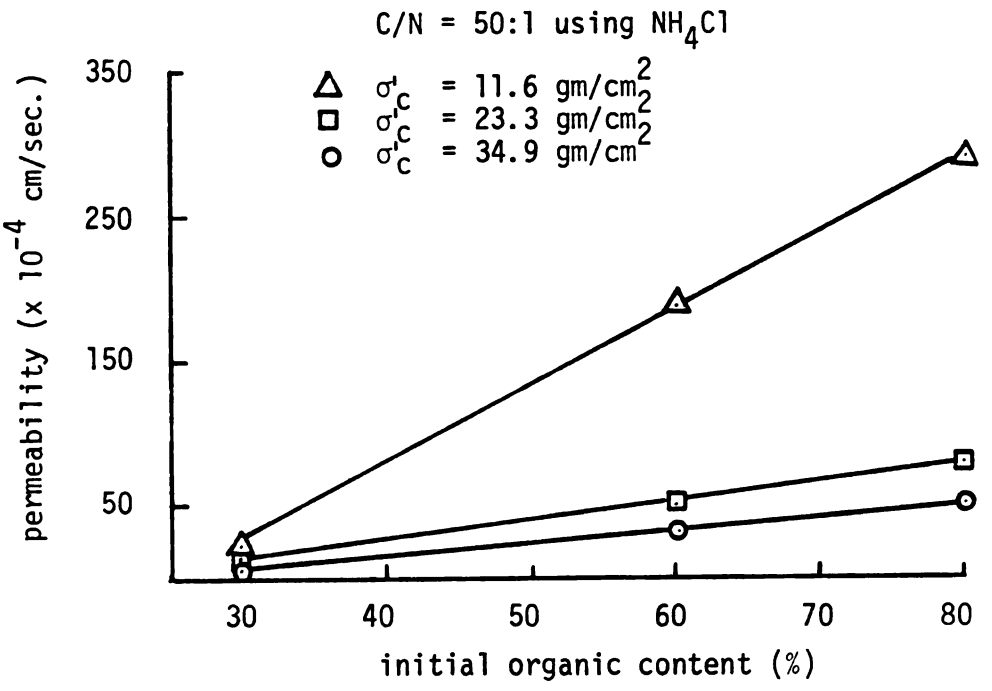
(d)

Figure 5.17.--Continued.



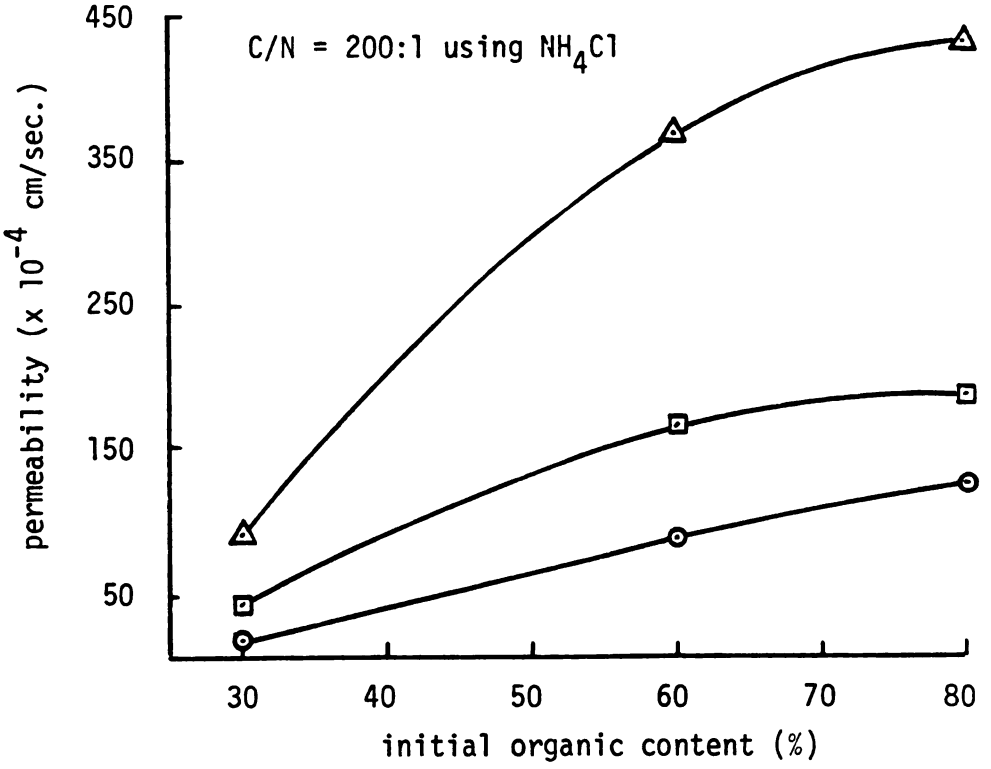
(e)

Figure 5.17.--Continued.



(f)

Figure 5.17.--Continued.



(g)

Figure 5.17.--Continued.

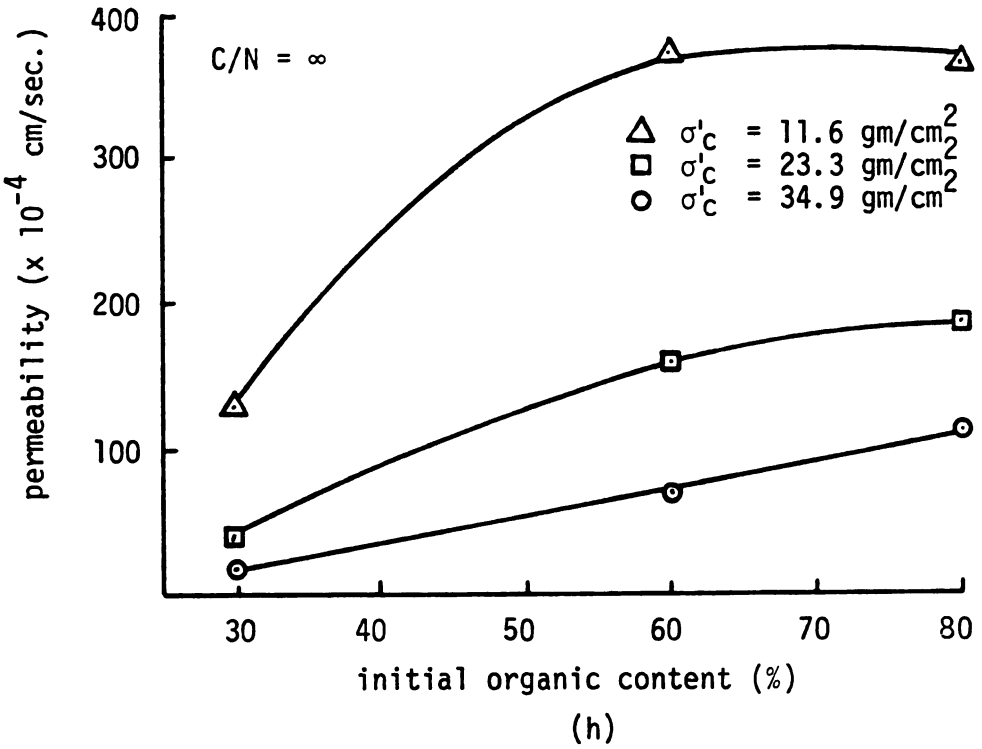


Figure 5.17.--Continued.

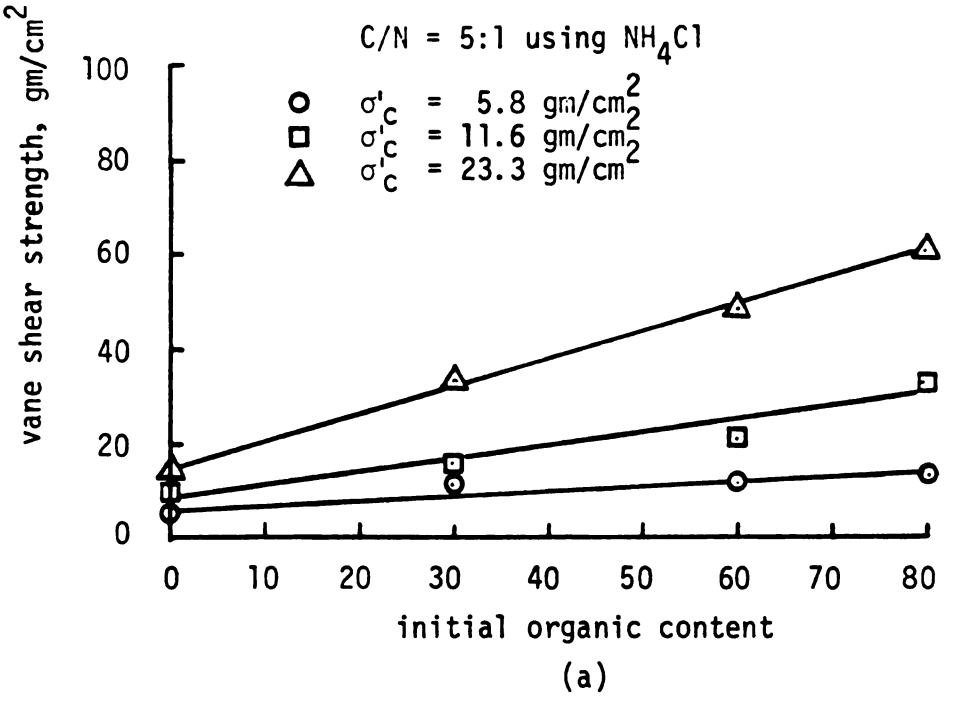
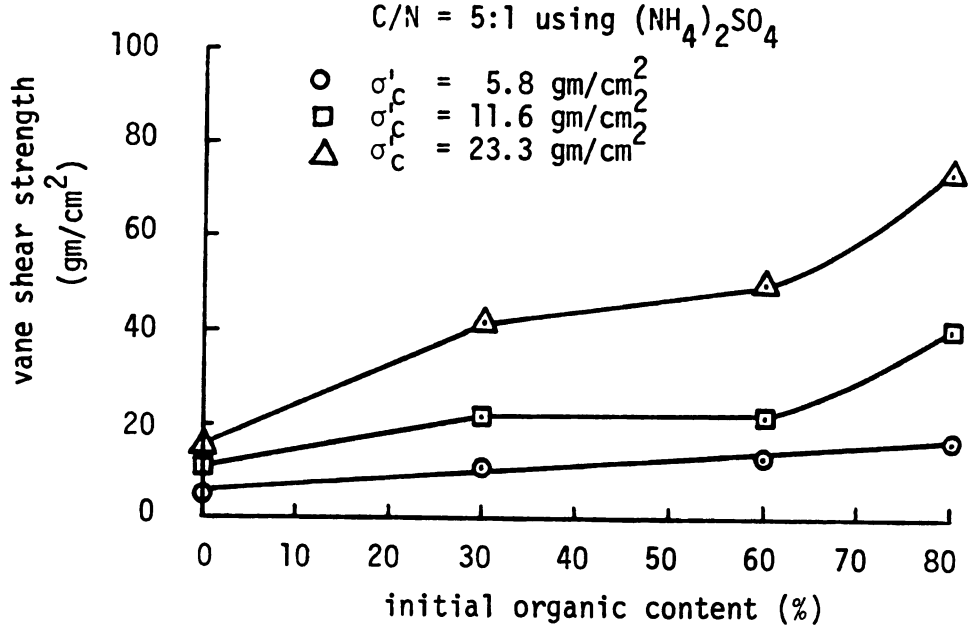
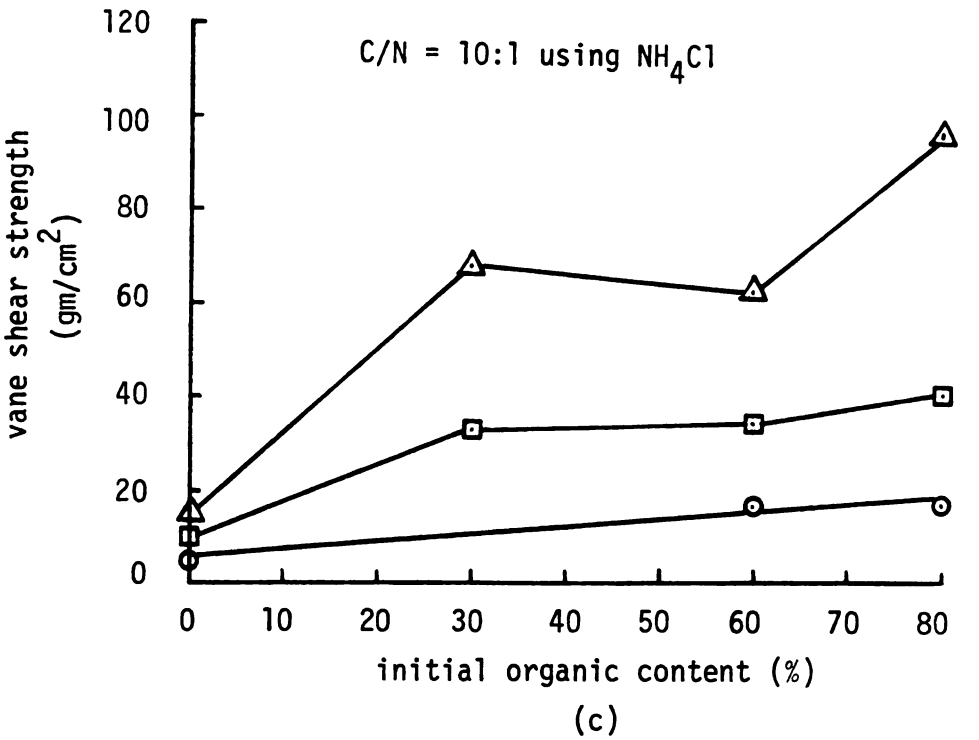


Figure 5.18.--Vane shear strength versus initial organic content, anaerobic conditions. (a) 5:1 carbon/nitrogen ratio (C/N), using NH_4Cl. (b) 5:1 C/N ratio, using $(NH_4)_2SO_4$. (c) 10:1 C/N ratio, using NH_4Cl. (d) 10:1 C/N ratio, using $(NH_4)_2SO_4$. (e) 30:1 C/N ratio, using NH_4Cl. (f) 50:1 C/N ratio, using NH_4Cl. (g) ∞:1 C/N ratio.



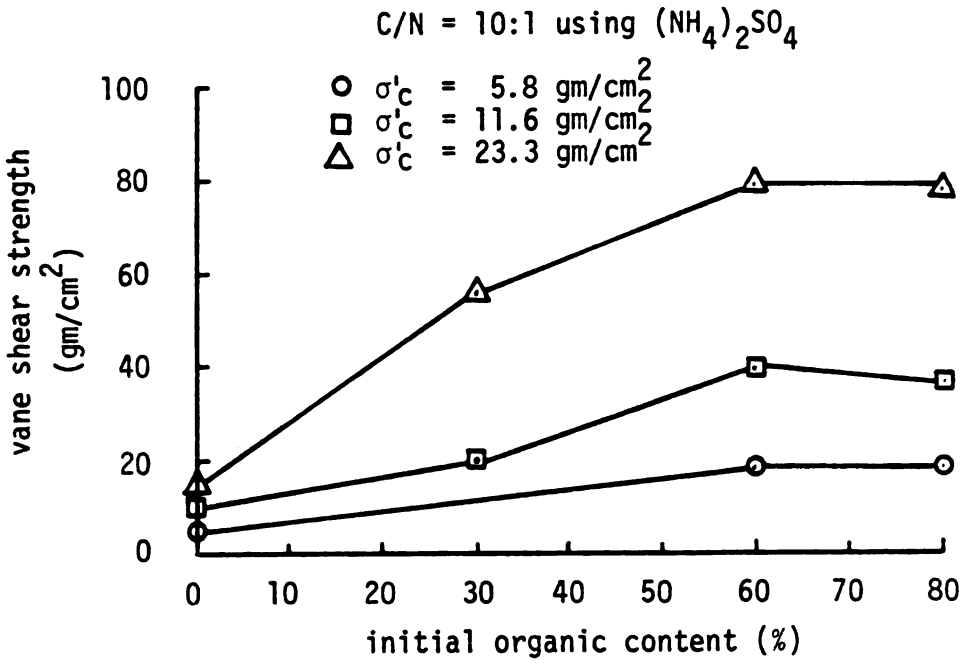
(b)

Figure 5.18.--Continued.



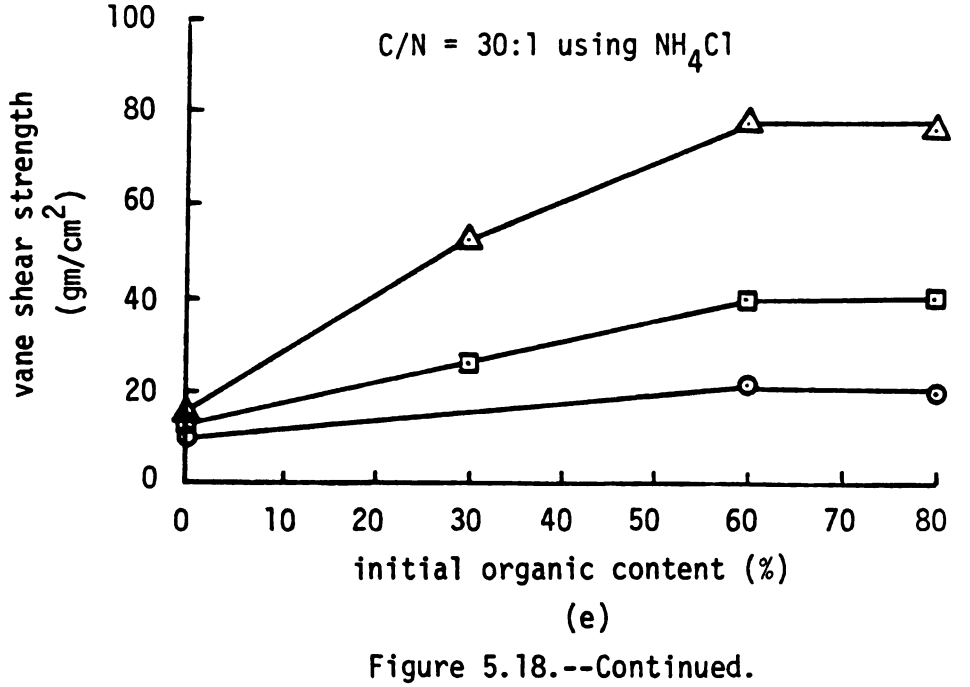
(c)

Figure 5.18.--Continued.



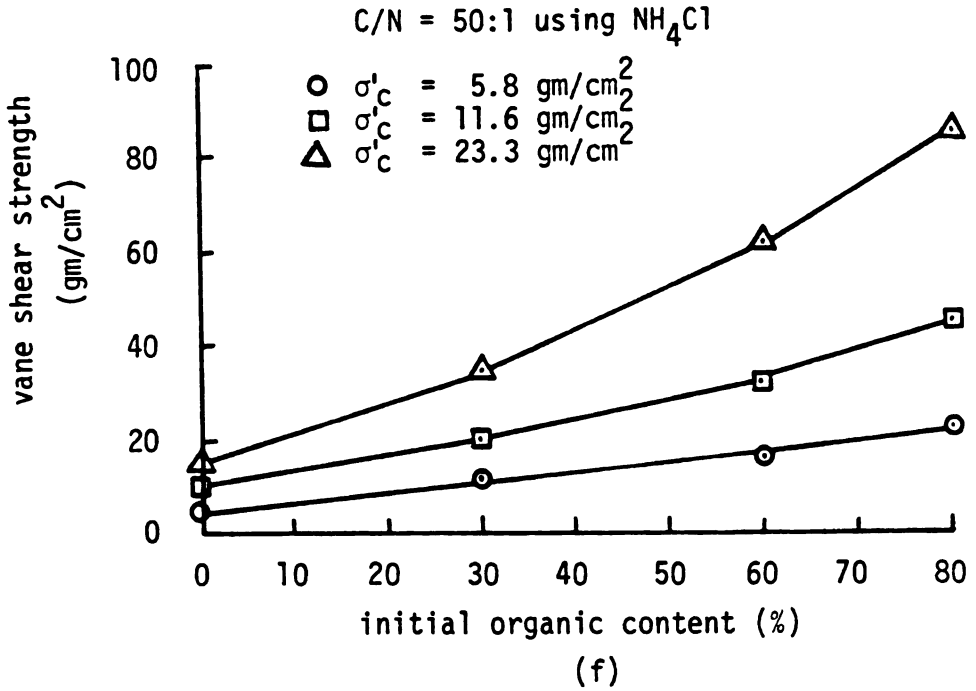
(d)

Figure 5.18.--Continued.



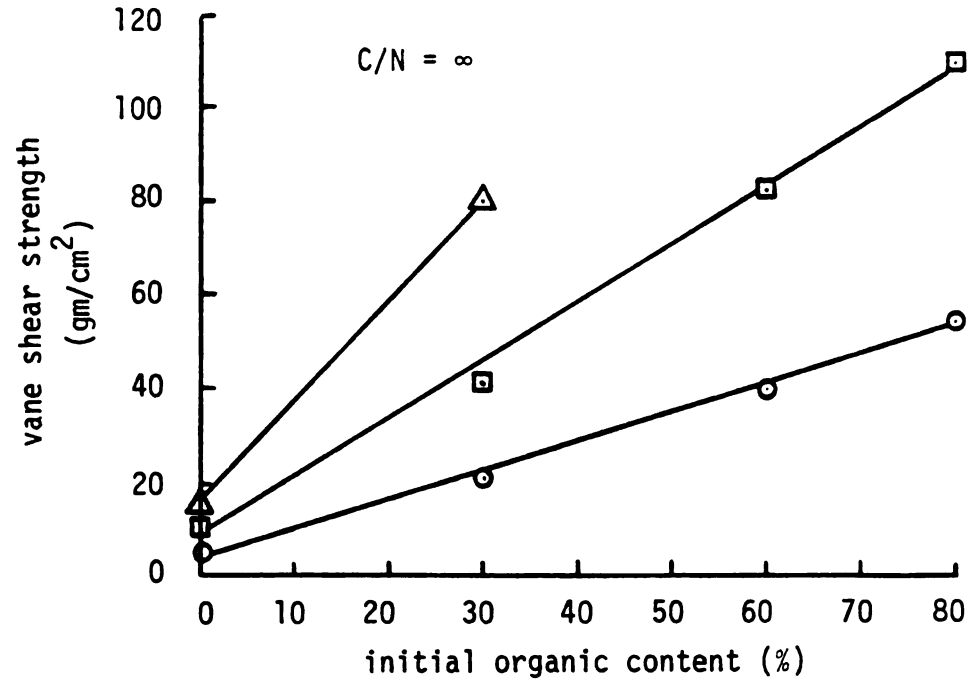
(e)

Figure 5.18.--Continued.



(f)

Figure 5.18.--Continued.



(g)

Figure 5.18.--Continued.

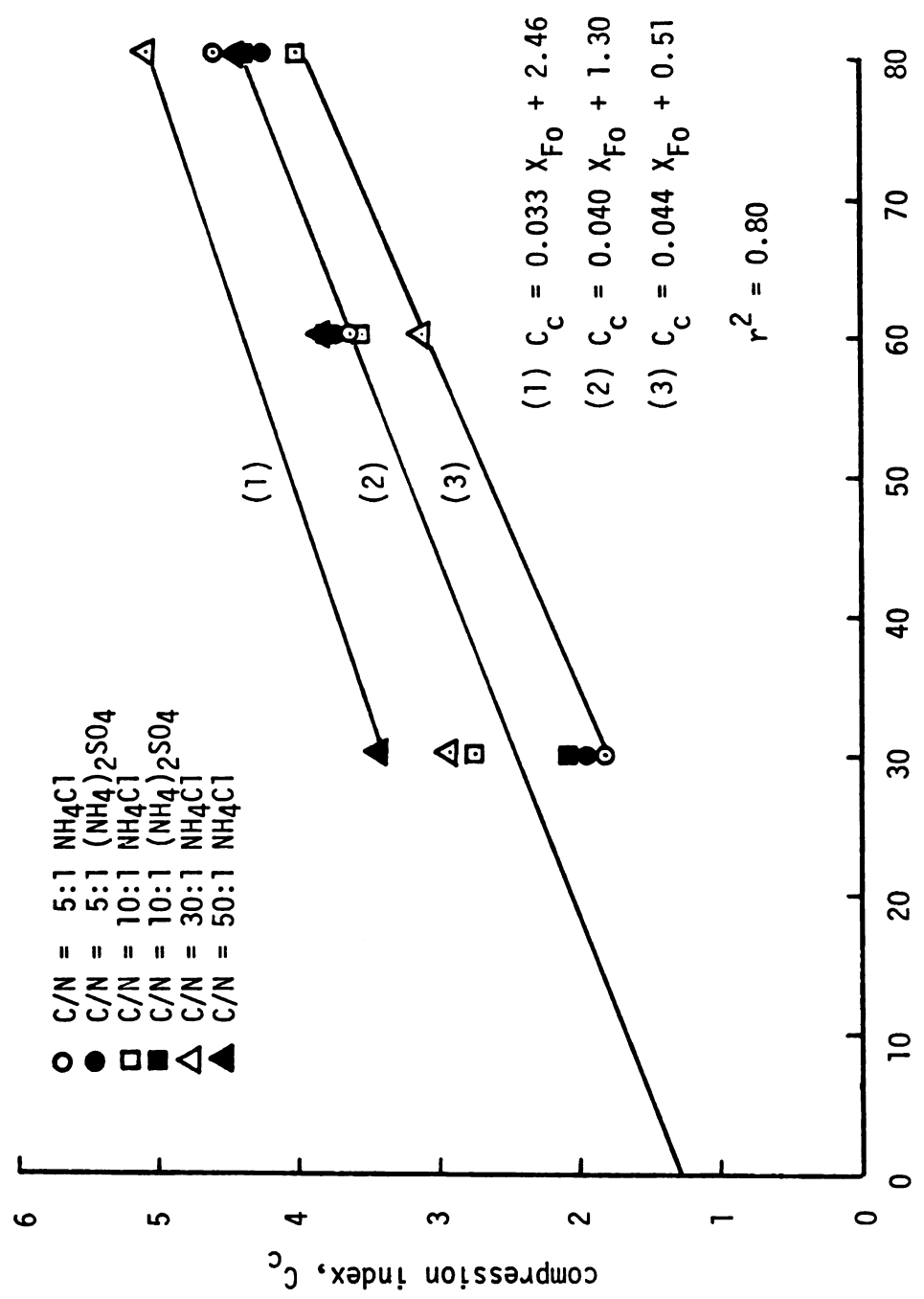
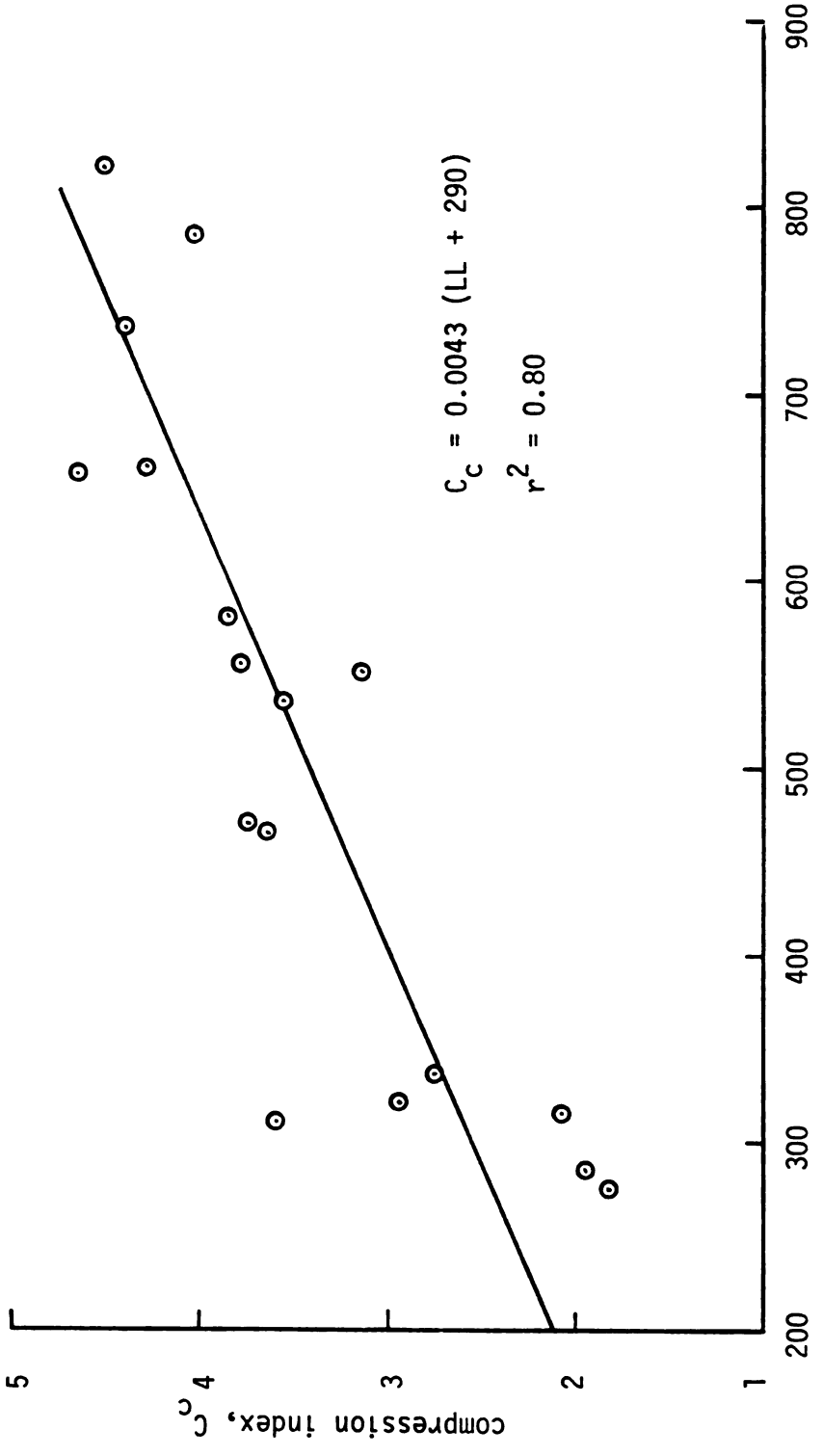


Figure 5.19.--Compression index for organic soils, anaerobic conditions. (a) organic content dependence. (b) equivalent liquid limit dependence.



(b)

Figure 5.19.--Continued.

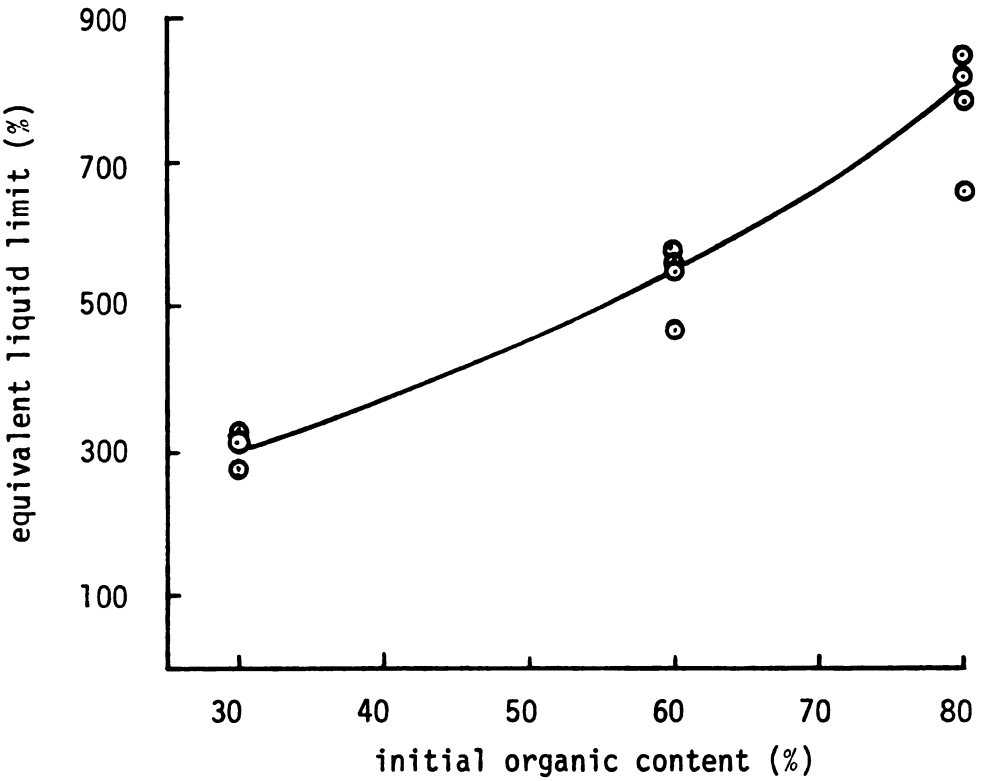


Figure 5.20.--Equivalent liquid limit versus initial organic content, anaerobic conditions.

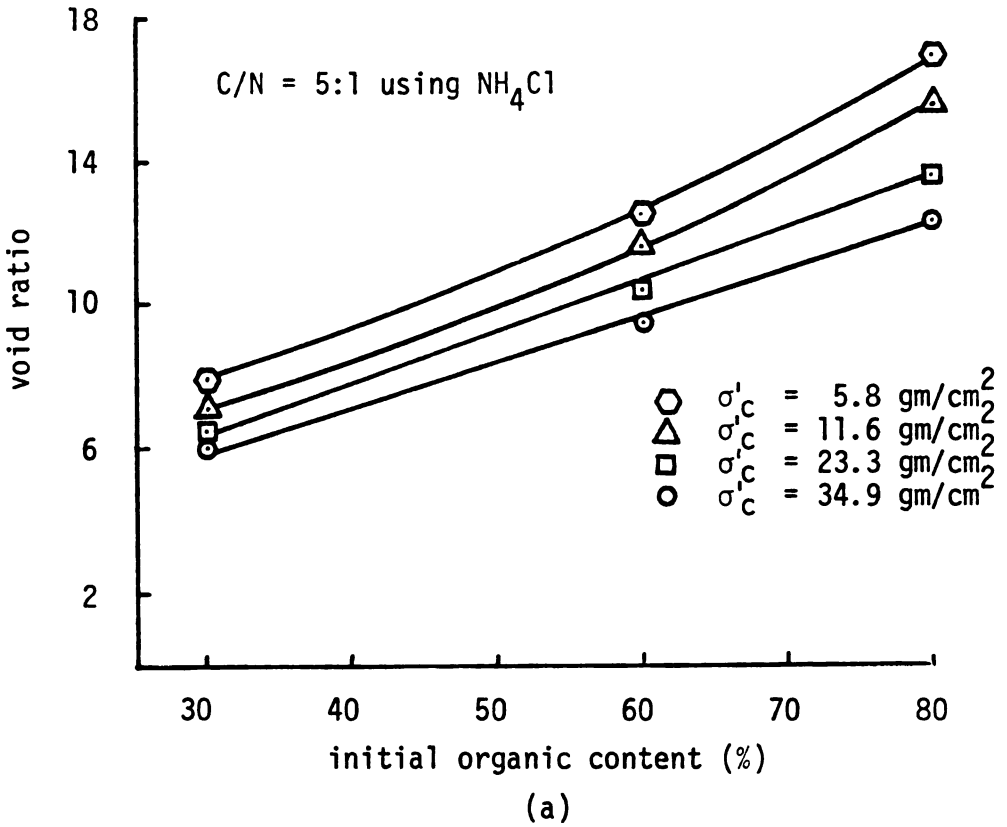
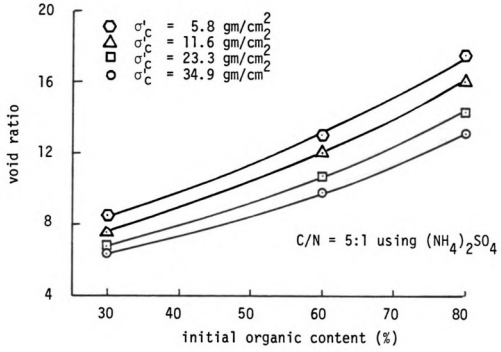
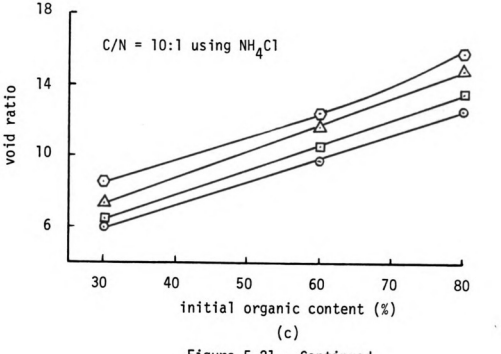


Figure 5.21.--Void ratio versus initial organic content, anaerobic conditions. (a) 5:1 carbon/ nitrogen ratio (C/N), using NH_4Cl. (b) 5:1 C/N ratio, using $(NH_4)_2SO_4$. (c) 10:1 C/N ratio, using NH_4Cl. (d) 10:1 C/N ratio, using $(NH_4)_2SO_4$. (e) 50:1 C/N ratio using NH_4Cl. (f) 200:1 C/N ratio, using NH_4Cl. (g) ∞:1 C/N ratio.



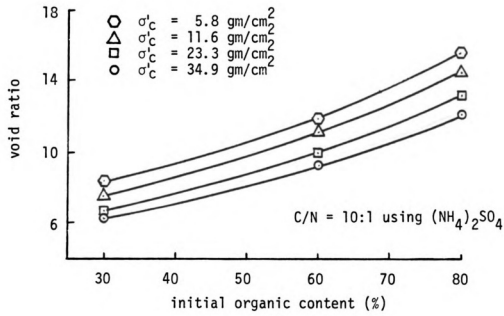
(b)

Figure 5.21.--Continued.



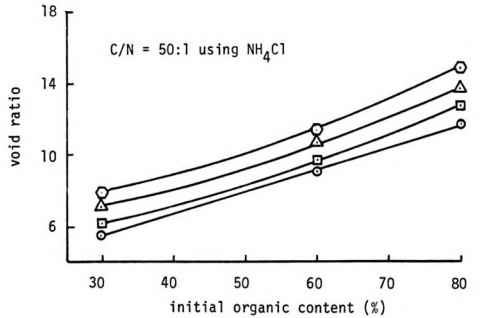
(c)

Figure 5.21.--Continued.



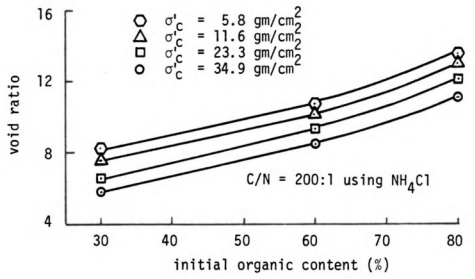
(d)

Figure 5.21.--Continued.



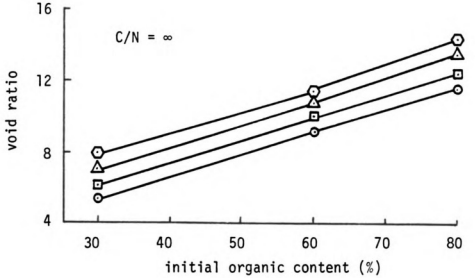
(e)

Figure 5.21.--Continued.



(f)

Figure 5.21.--Continued.



(g)

Figure 5.21.--Continued.

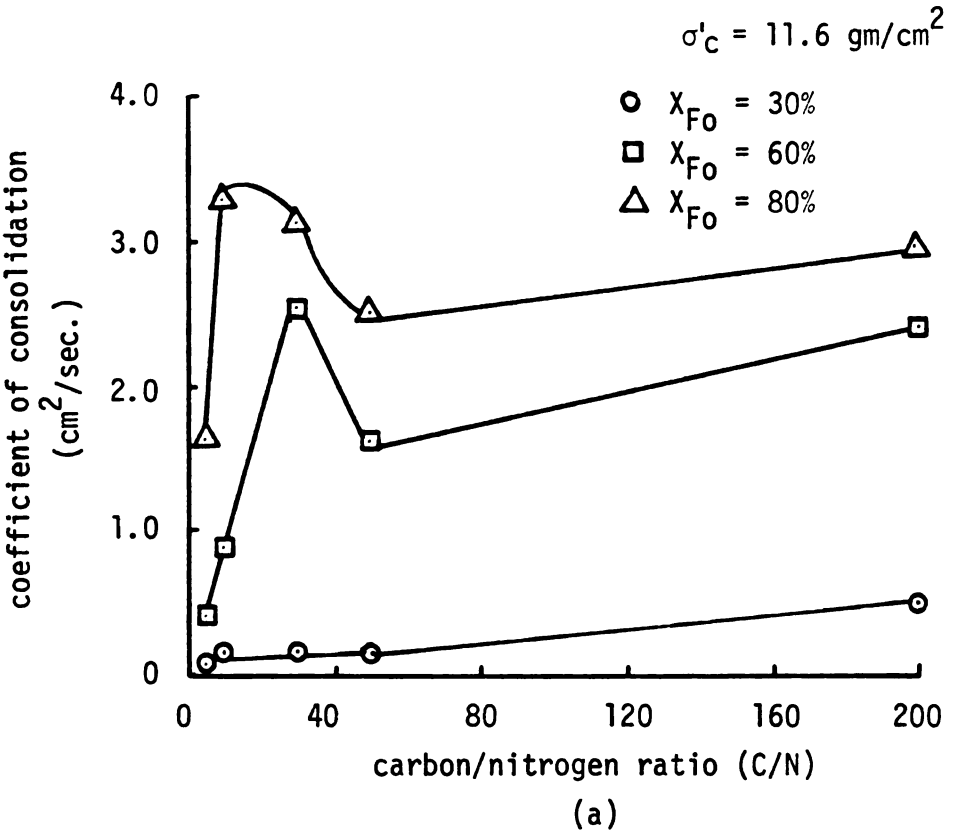
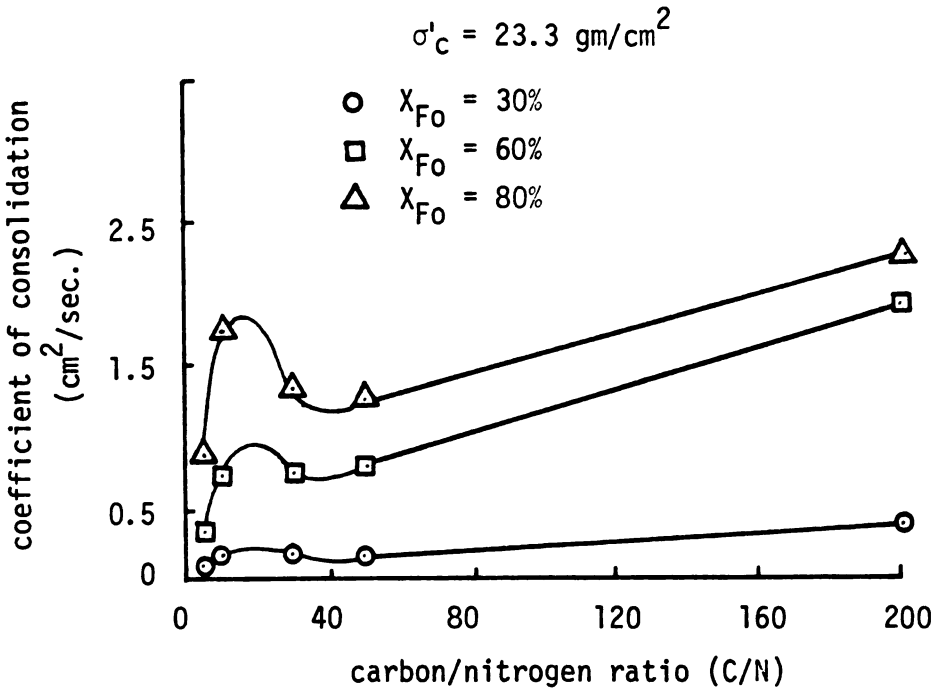
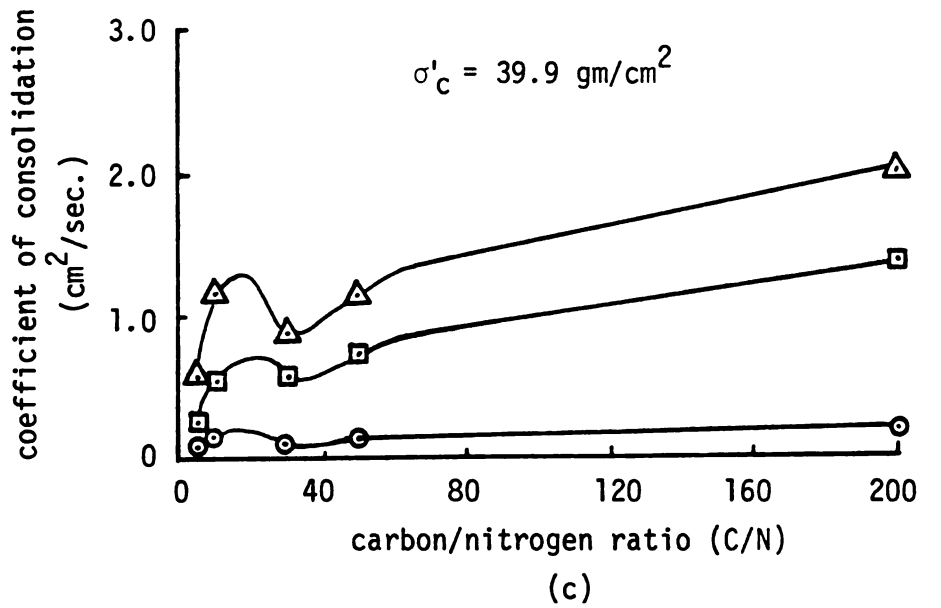


Figure 5.22.--Coefficient of consolidation versus carbon/nitrogen ratio, anaerobic conditions. (a) 11.6 gm/cm^2 effective consolidation pressure (σ'_c). (b) 23.3 gm/cm^2 σ'_c. (c) 34.9 gm/cm^2 σ'_c.



(b)

Figure 5.22.--Continued.



(c)

Figure 5.22.--Continued.

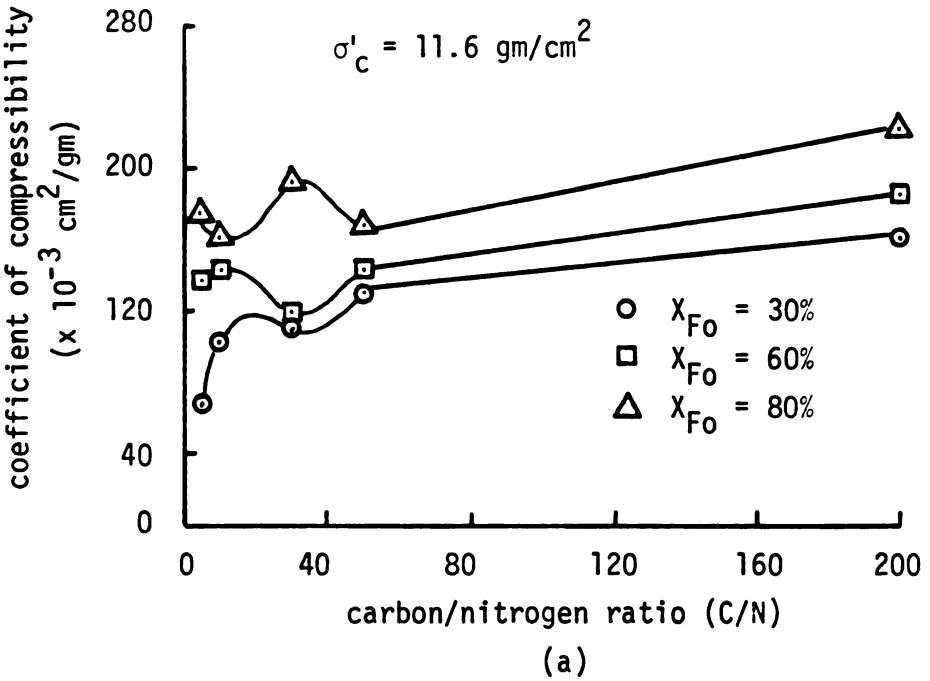
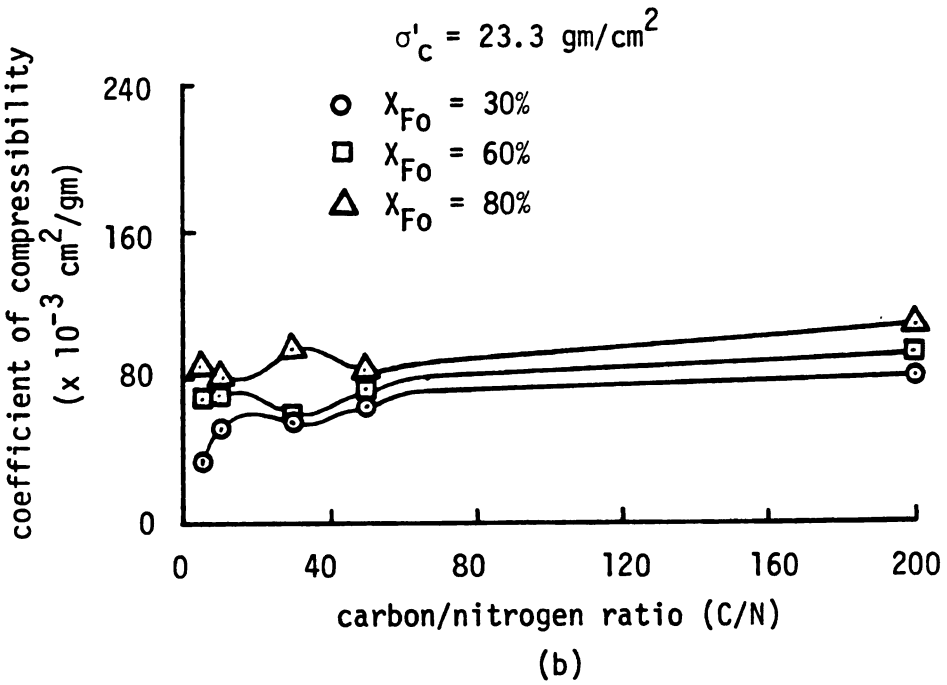
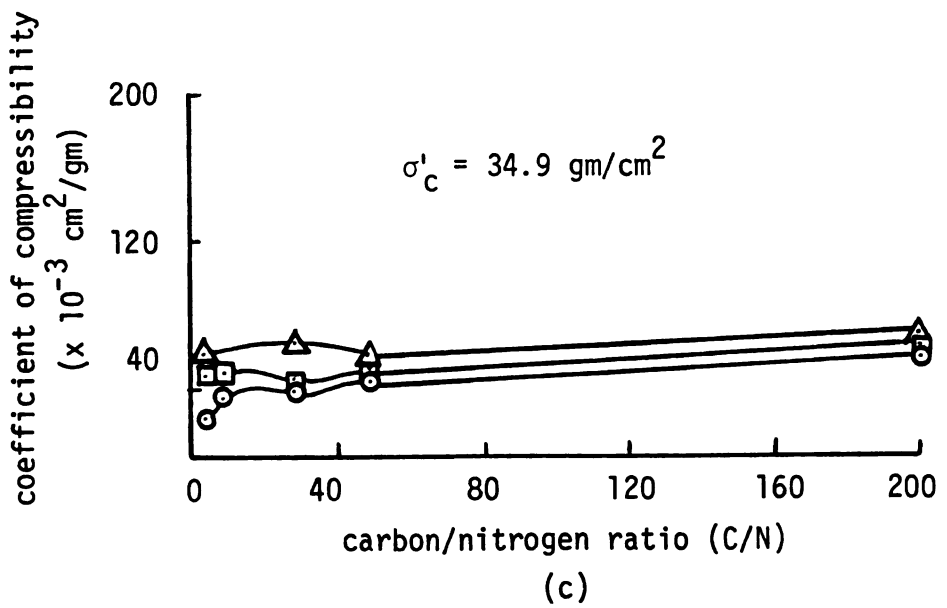


Figure 5.23.--Coefficient of compressibility versus carbon/nitrogen ratio, anaerobic conditions. (a) 11.6 gm/cm^2 effective consolidation pressure (σ'_c). (b) 23.3 gm/cm^2 σ'_c. (c) 34.9 gm/cm^2 σ'_c.



(b)

Figure 5.23.--Continued.



(c)

Figure 5.23.--Continued.

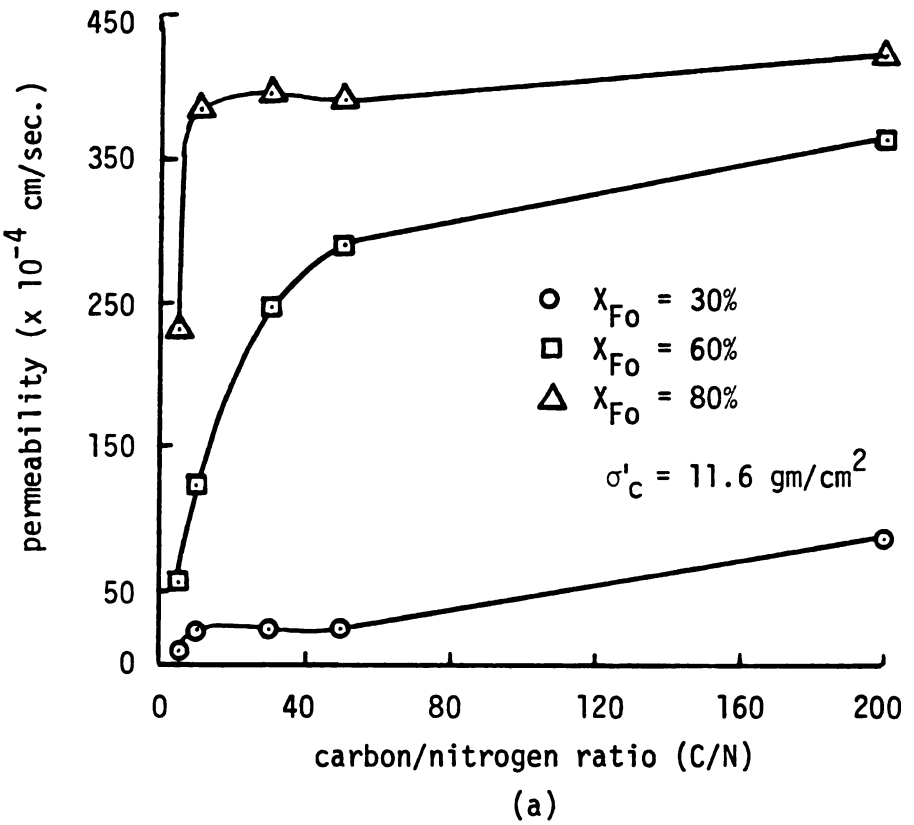
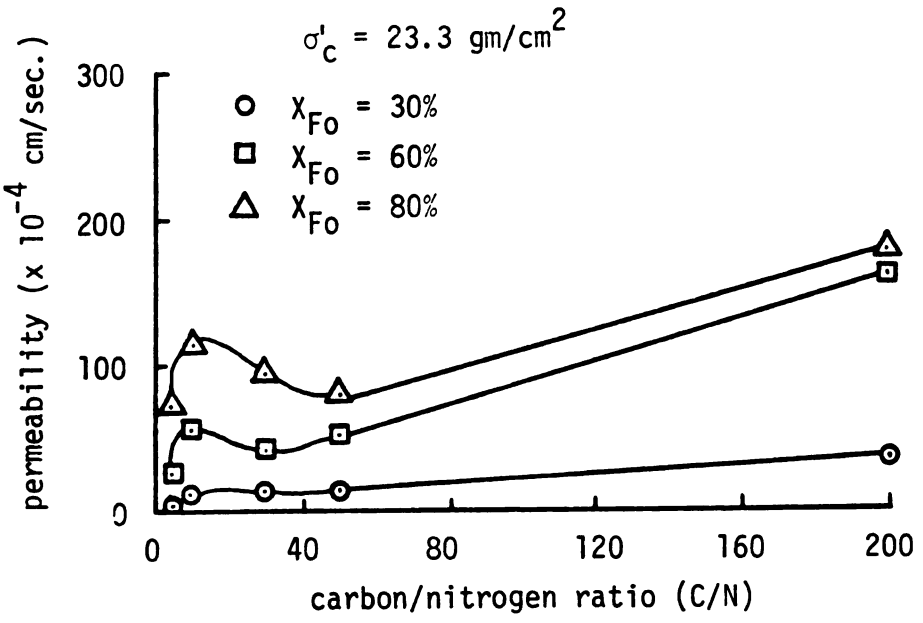


Figure 5.24.--Coefficient of permeability versus carbon/nitrogen ratio, anaerobic conditions. (a) 11.6 gm/cm^2 effective consolidation pressure (σ'_c). (b) 23.3 gm/cm^2 σ'_c. (c) 34.9 gm/cm^2 σ'_c.



(b)

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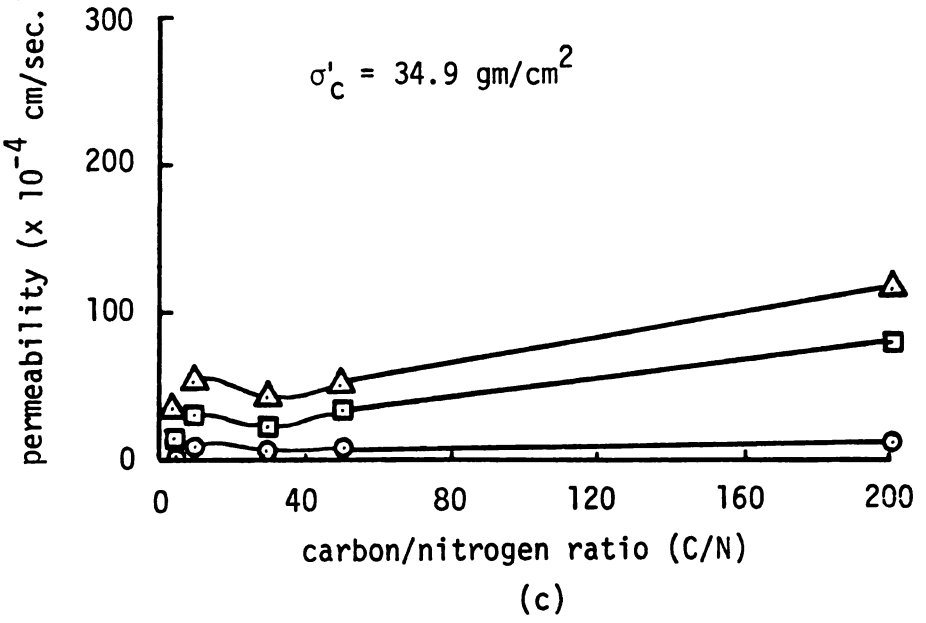
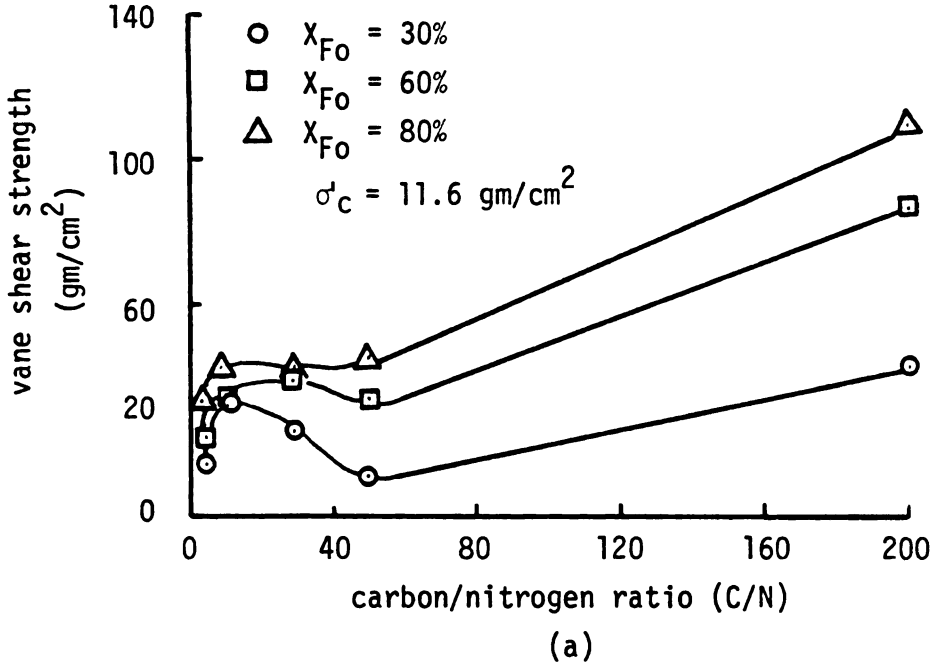
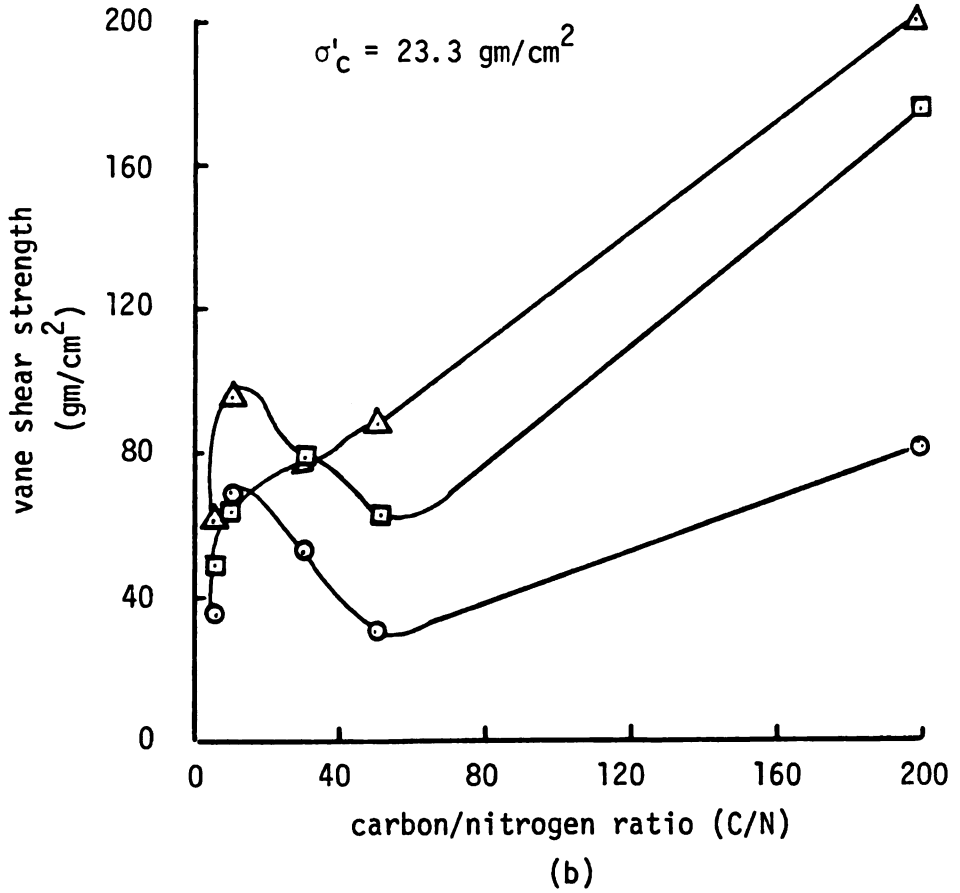


(c)

Figure 5.24.--Continued.



(a)



(b)

Figure 5.25.--Vane shear strength versus C/N ratio.
(a) 11.6 gm/cm^2 σ'_c. (b) 23.3 gm/cm^2 σ'_c

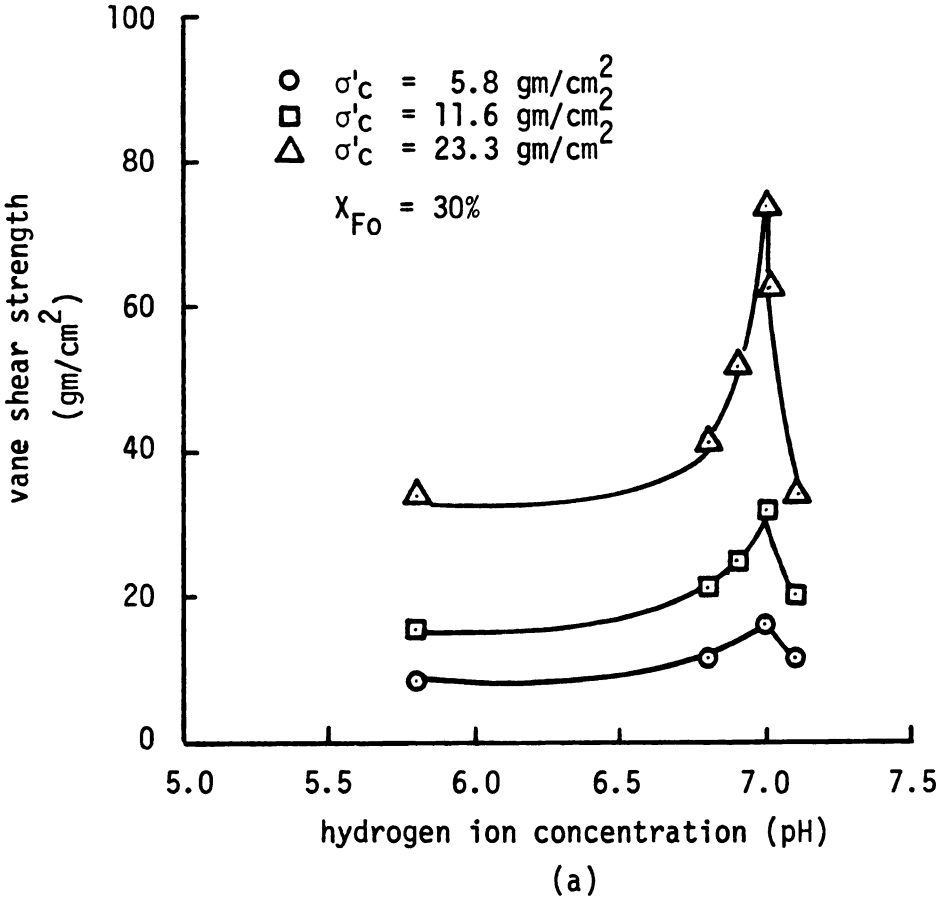
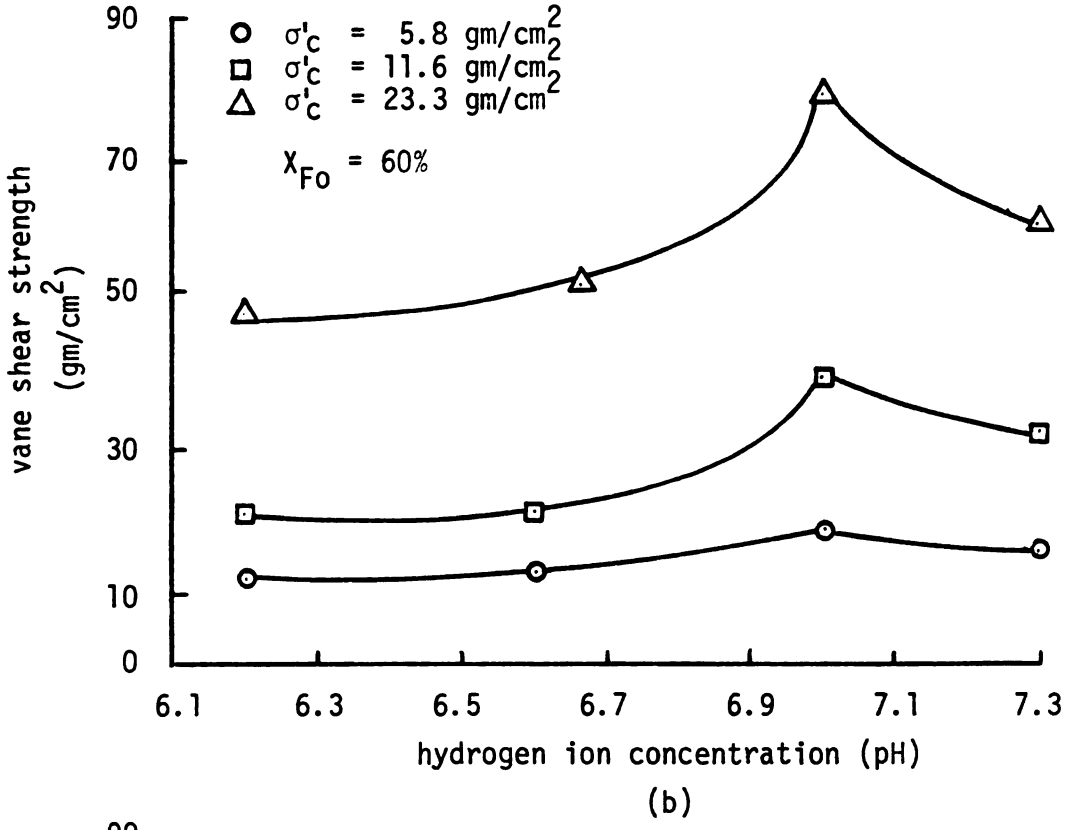
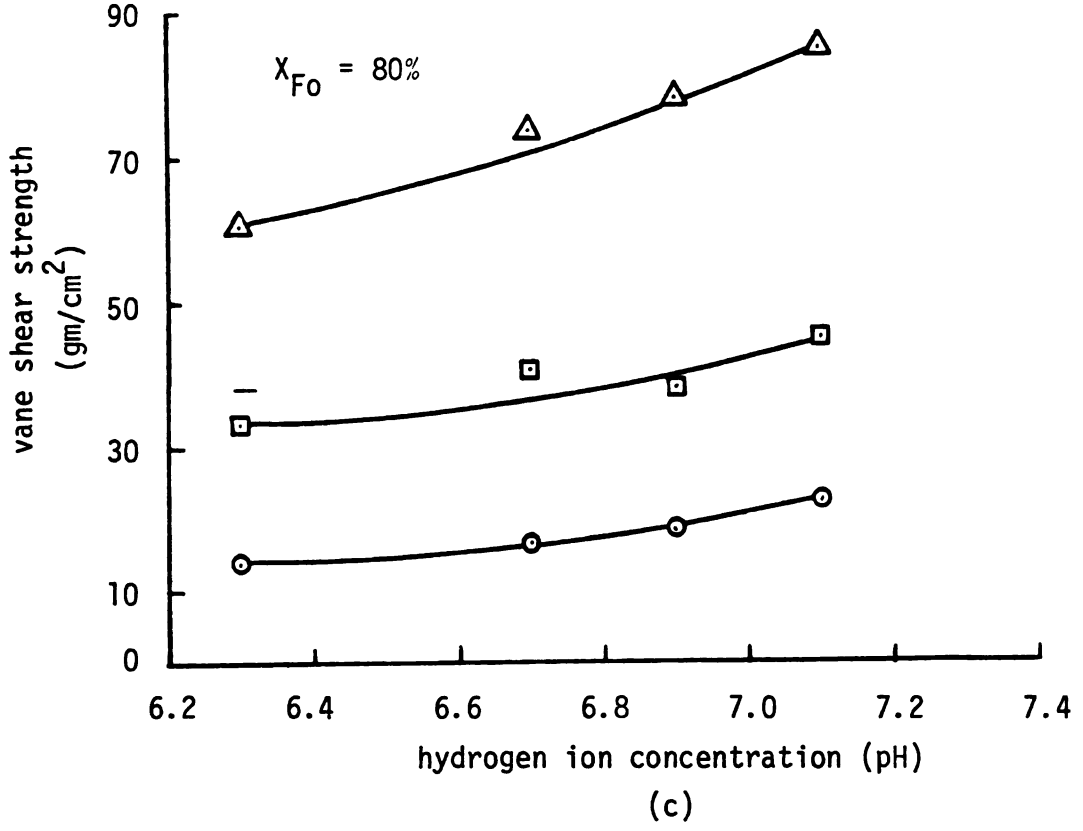


Figure 5.26.--Vane shear strength versus pH, anaerobic conditions. (a) 30% initial organic content (X_{Fo}). (b) 60% X_{Fo}. (c) 80% X_{Fo}.



(b)



(c)

Figure 5.26.--Continued.

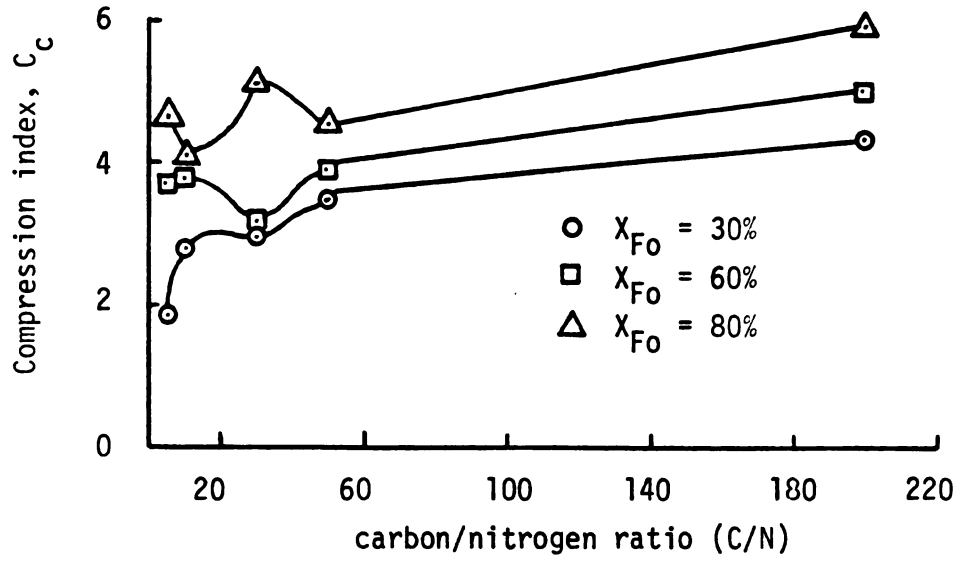


Figure 5.27.--Compression index versus carbon/nitrogen ratio, anaerobic conditions.

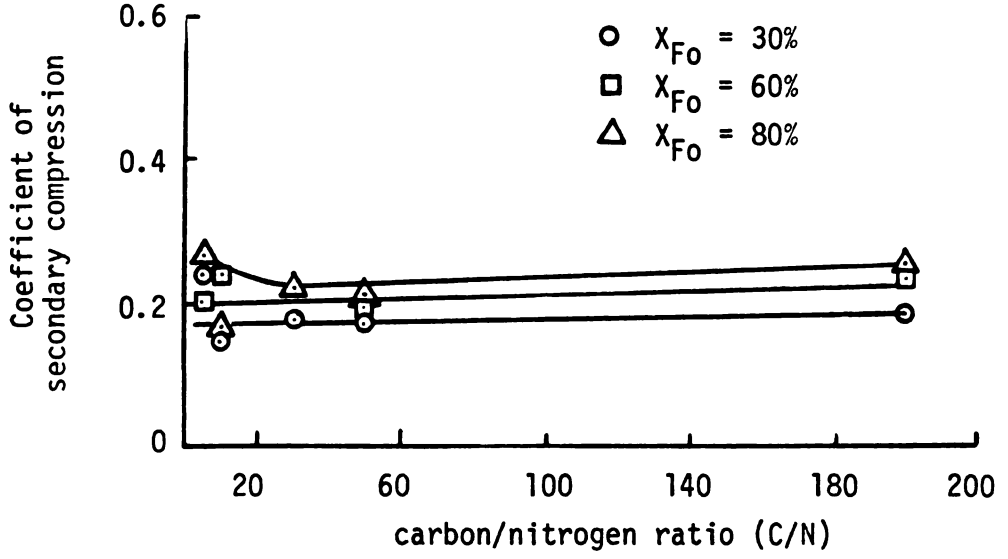


Figure 5.28.--Coefficient of secondary compression versus carbon/nitrogen ratio, anaerobic conditions.

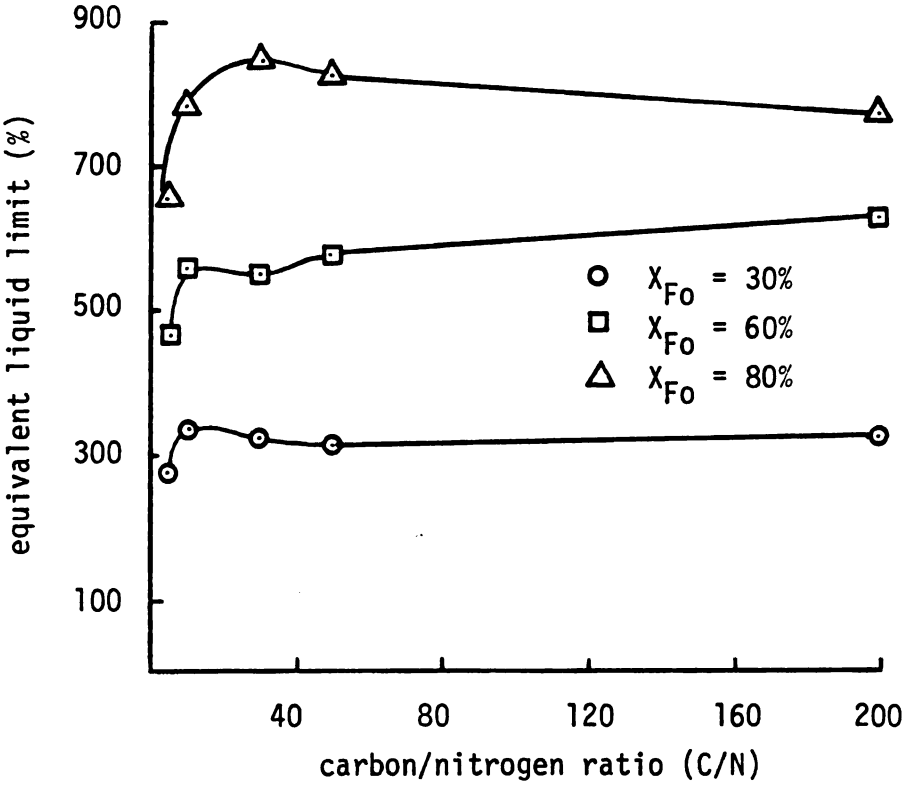
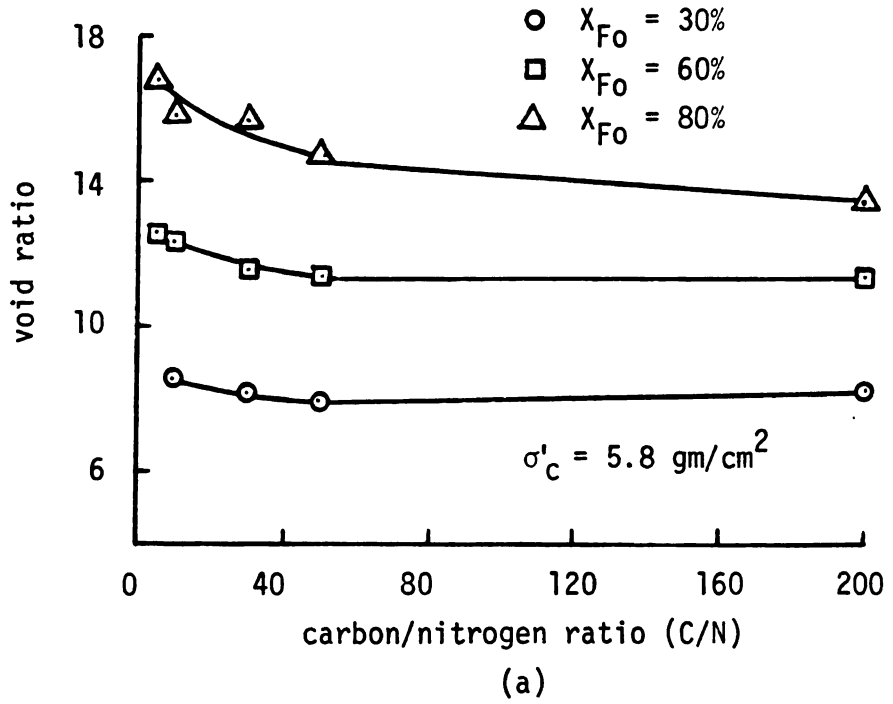
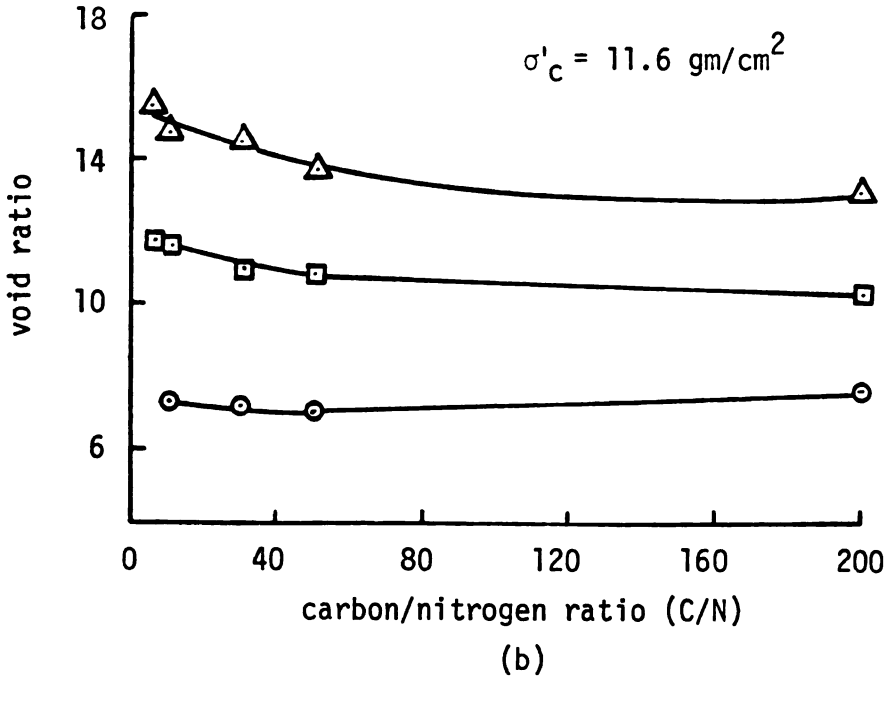


Figure 5.29.--Equivalent liquid limit versus carbon/nitrogen ratio, anaerobic conditions.

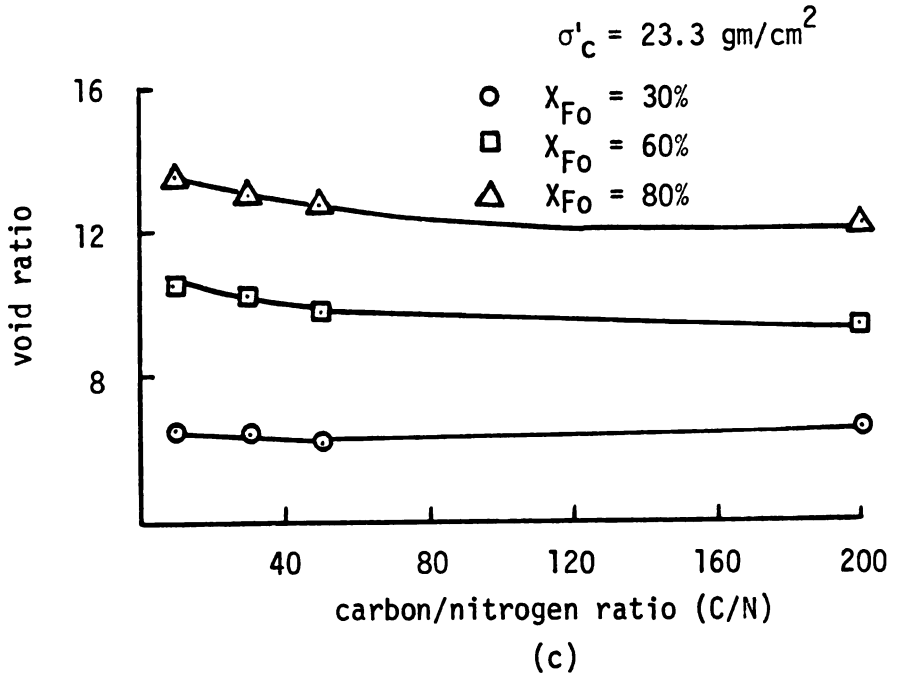


(a)

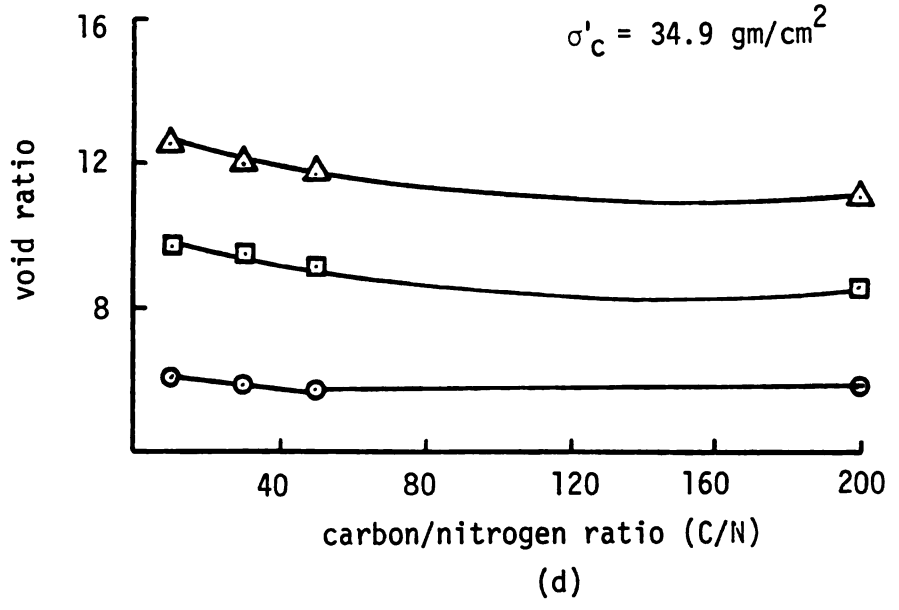
Figure 5.30.--Void ratio versus carbon/nitrogen ratio, anaerobic conditions. (a) 5.8 gm/cm^2 effective consolidation pressure (σ'_c). (b) 11.6 gm/cm^2 σ'_c. (c) 23.3 gm/cm^2 σ'_c. (d) 34.9 gm/cm^2 σ'_c.



(b)



(c)



(d)

Figure 5.30.--Continued.

TABLE 5.1.--Coefficient of Compressibility for Decomposed Samples (X_{FO} = 30%)

a_{vo} cm^2/gm	a_{vI} cm^2/gm	a_{vI}/a_{vo} (%)	X_{DI} (%)	σ'_c gm/cm^2	$(C/N)_o$ (%)
.0563	.0766	1.36		11.6	
.0280	.0256	1.37	16.65	23.3	5
.0187	.0256	1.37		34.9	
.0548	.0740	1.35		11.6	
.0273	.0370	1.36	44.85	23.3	10
.0182	.0247	1.36		34.9	
.0379	.0347	0.92		11.6	
.0188	.0174	0.93	52.27	23.3	50
.0126	.0116	0.92		34.9	

TABLE 5.2.--Permeability of Decomposed Samples K_I for X_{FO} = 30%, Aerobic

k_o cm/sec.	k_I cm/sec.	k_I/k_o (%)	X_{DI} (%)	σ'_c gm/cm^2	$(C/N)_o$ (%)
.00658	.00026	.04		11.6	
.00258	.00012	.04	16.65	23.3	5
.00065	.00002	.03		34.9	
.01288	.00002	.002		11.6	
.00425	.00002	.002	44.85	23.3	10
.00307	.00002	.007		34.9	
.00488	.000034	.007		11.6	
.00207	.000011	.005	52.27	23.3	50
.00103	.000018	.002		34.9	

TABLE 5.3.--Vane Shear Strength of Decomposed Samples (S_{UI}) for 30% Initial Organic Content

S_{uo} gm/cm^2	S_{UI} gm/cm^2	S_{UI}/S_{uo} (%)	X_{DI} (%)	σ'_c gm/cm^2	$(C/N)_o$ (%)
32.03	14.75	0.46	16.65		5
30.10	8.35	0.28	44.85	5.8	10
55.68	11.50	0.21	52.27		50

TABLE 5.4.--Height of Decomposed Samples H_I for 30% Initial Organic Content

H_o (cm)	H_I (cm)	H_I/H_o (%)	X_{DI} (%)	σ'_c gm/cm^2	$(C/N)_o$ (%)
12.19	8.56	0.70		11.6	
11.71	7.85	0.67	16.65	23.3	5
11.29	7.11	0.63		34.9	
11.81	6.40	0.54		11.6	
11.40	5.84	0.51	44.85	23.3	10
10.95	5.51	0.50		34.9	
10.80	6.40	0.59		11.6	
10.52	5.94	0.56	52.27	23.3	50
10.19	5.72	0.56		34.9	

TABLE 5.5.--Coefficient of Consolidation for Decomposed Samples (C_{vI})

C_{vo} $cm^2/sec.$	C_{vI} $cm^2/sec.$	C_{vI}/C_{vo} (%)	X_{DI} (%)	σ'_c (gm/cm^2)	X_{FO} (%)	C/N (%)
.0983	.5462	5.56	10.40			5
.1710	.0237	0.14	54.18	11.6	30	10
.5075	.6312	1.24	23.9			200
.0866	.2000	2.31	10.40			5
.1560	.0237	0.15	54.18	23.3	30	10
.3731	.3789	1.07	23.9			200
.0738	.1355	1.84	10.40			5
.1415	.0098	0.07	54.18	34.9	30	10
.1581	.1667	1.05	23.9			200
.4271	.9978	2.34	20.00	11.6	60	5
2.386	1.898	0.80	41.05			200
.2285	.3591	1.06	20.00	23.3	60	5
1.924	.7849	.41	41.05			200
.2515	.3323	1.32	20.00	34.9	60	5
1.341	.1860	.14	41.05			200
1.631	1.167	.72	43.32	11.6	80	5
2.923	1.966	.67	60.42			200
.8959	.4968	.55	43.32	23.3	80	5
2.255	.772	.34	60.42			200
.5919	.4828	.82	43.32	34.9	80	5
2.045	.3376	.17	60.42			200

TABLE 5.6.--Void Ratios Under Different Consolidation Pressures

	H			e		
σ_c	H_o	H_I	H_I/H_o	e_o	e_I	e_I/e_o
5.8	4.75	4.38	0.92	7.94	8.00	1.00
11.6	4.35	4.15	0.95	7.18	7.54	1.05
23.3	3.94	3.82	0.97	6.41	6.85	1.07
34.9	3.73	3.57	0.96	6.02	6.34	1.05
5.8	5.00	3.13	0.63	8.52	7.196	0.84
11.6	4.36	2.71	0.62	7.30	6.104	0.84
23.3	3.88	2.50	0.64	6.39	5.54	0.87
34.9	3.69	2.35	0.64	6.03	5.15	0.85
5.8	4.81	3.95	0.82	8.19	8.46	1.08
11.6	4.54	3.54	0.78	7.67	7.25	0.95
23.3	3.95	3.01	0.76	6.54	6.01	0.92
34.9	3.57	2.68	0.75	5.82	5.25	0.90

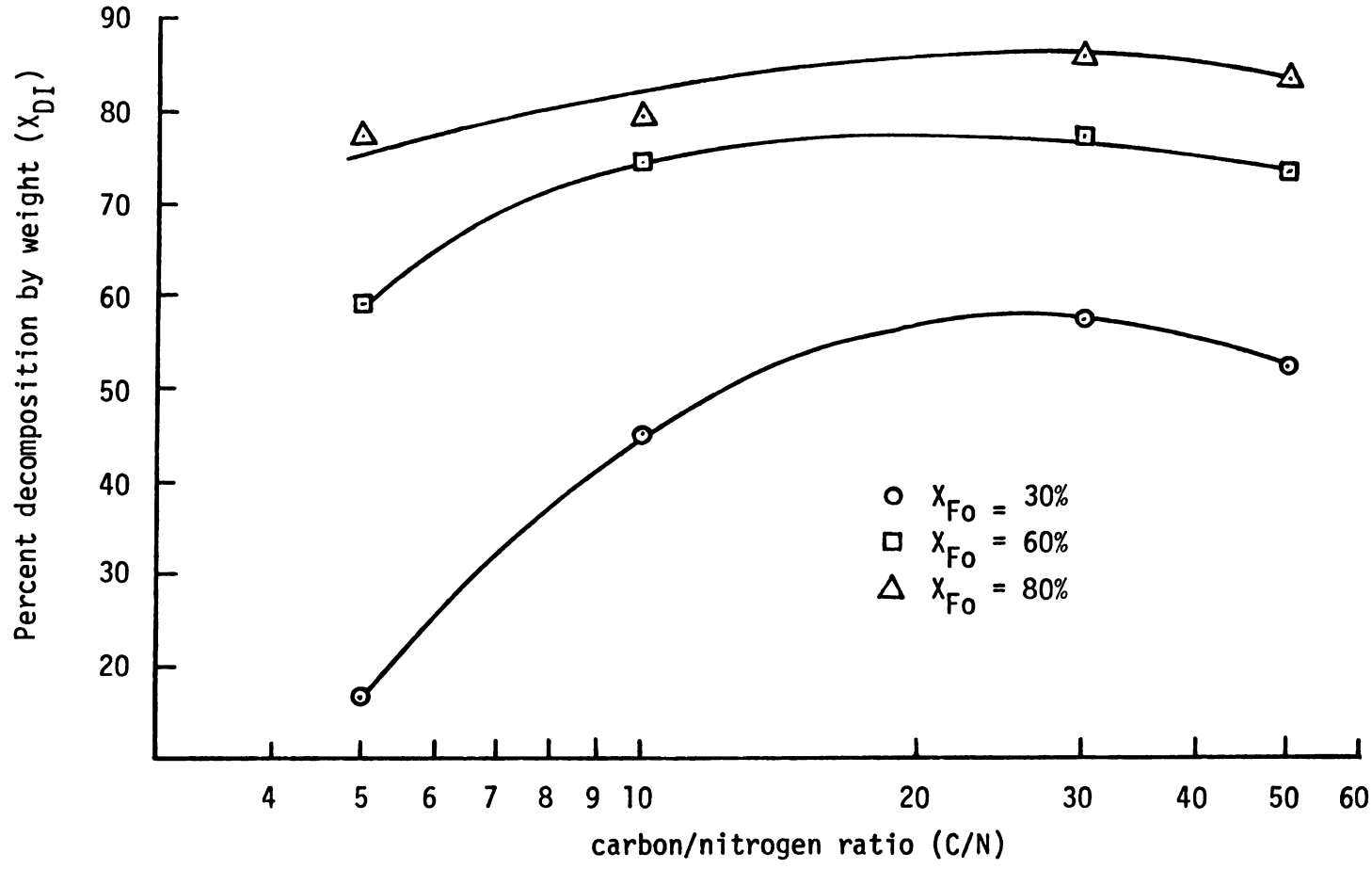


Figure 5.31.--Percent decomposition versus carbon/nitrogen ratio, aerobic conditions.

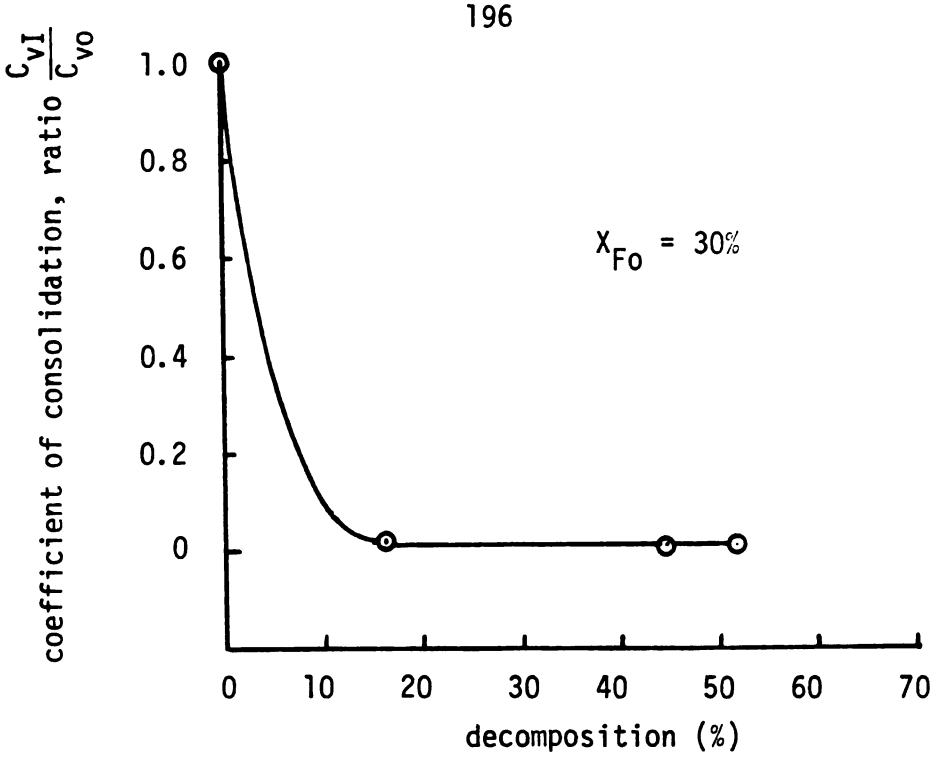


Figure 5.32.--Coefficient of consolidation, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

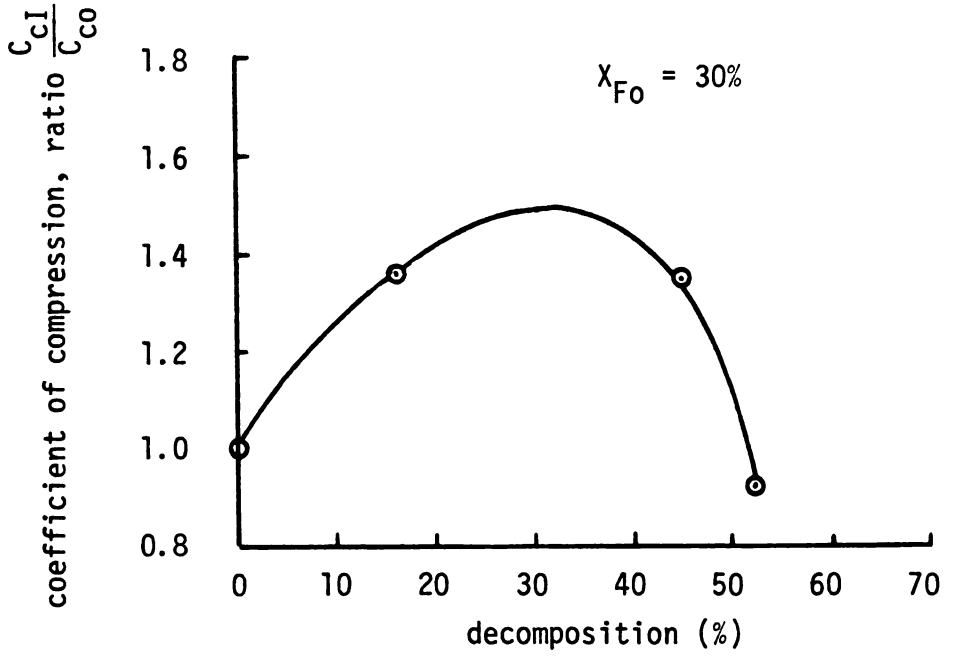


Figure 5.33.--Coefficient of compression, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

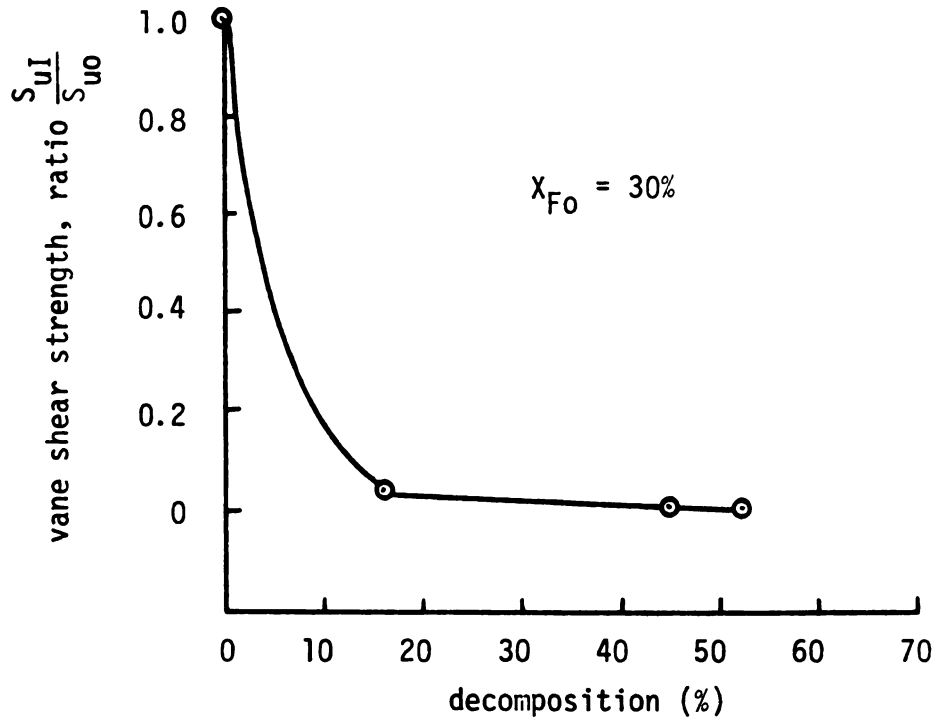


Figure 5.34.--Coefficient of permeability, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

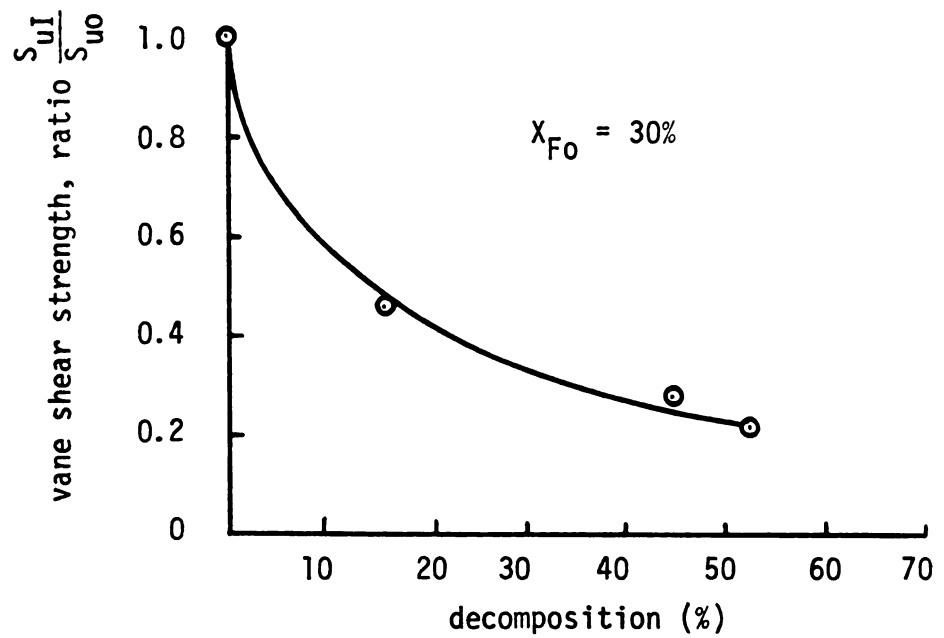


Figure 5.35.--Vane shear strength, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

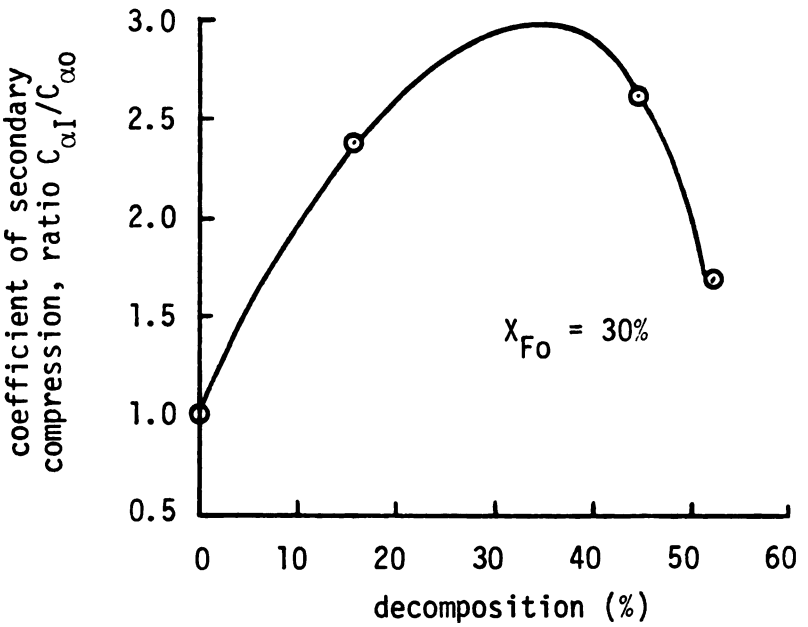


Figure 5.36.--Coefficient of secondary compression, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

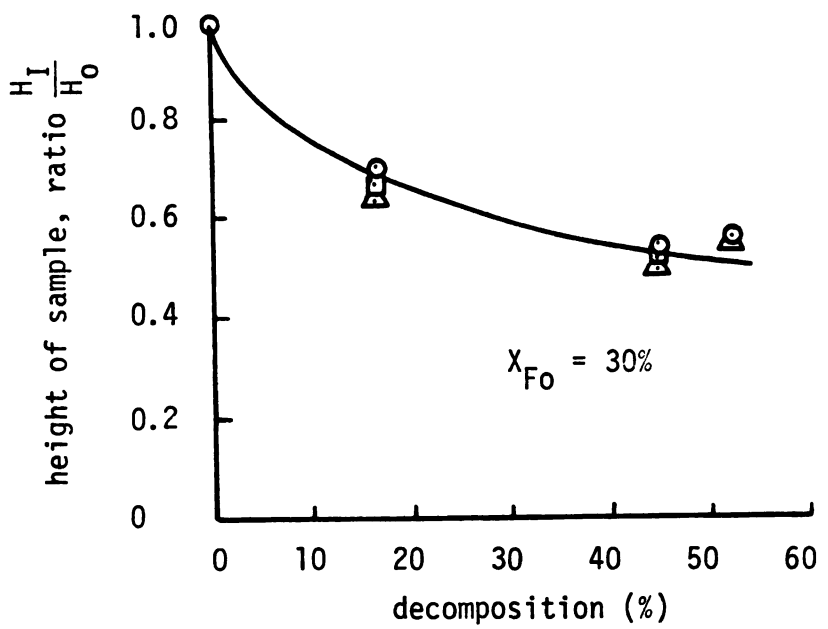


Figure 5.37.--Height of sample, ratio of decomposed to initial value, versus percent decomposition, aerobic conditions.

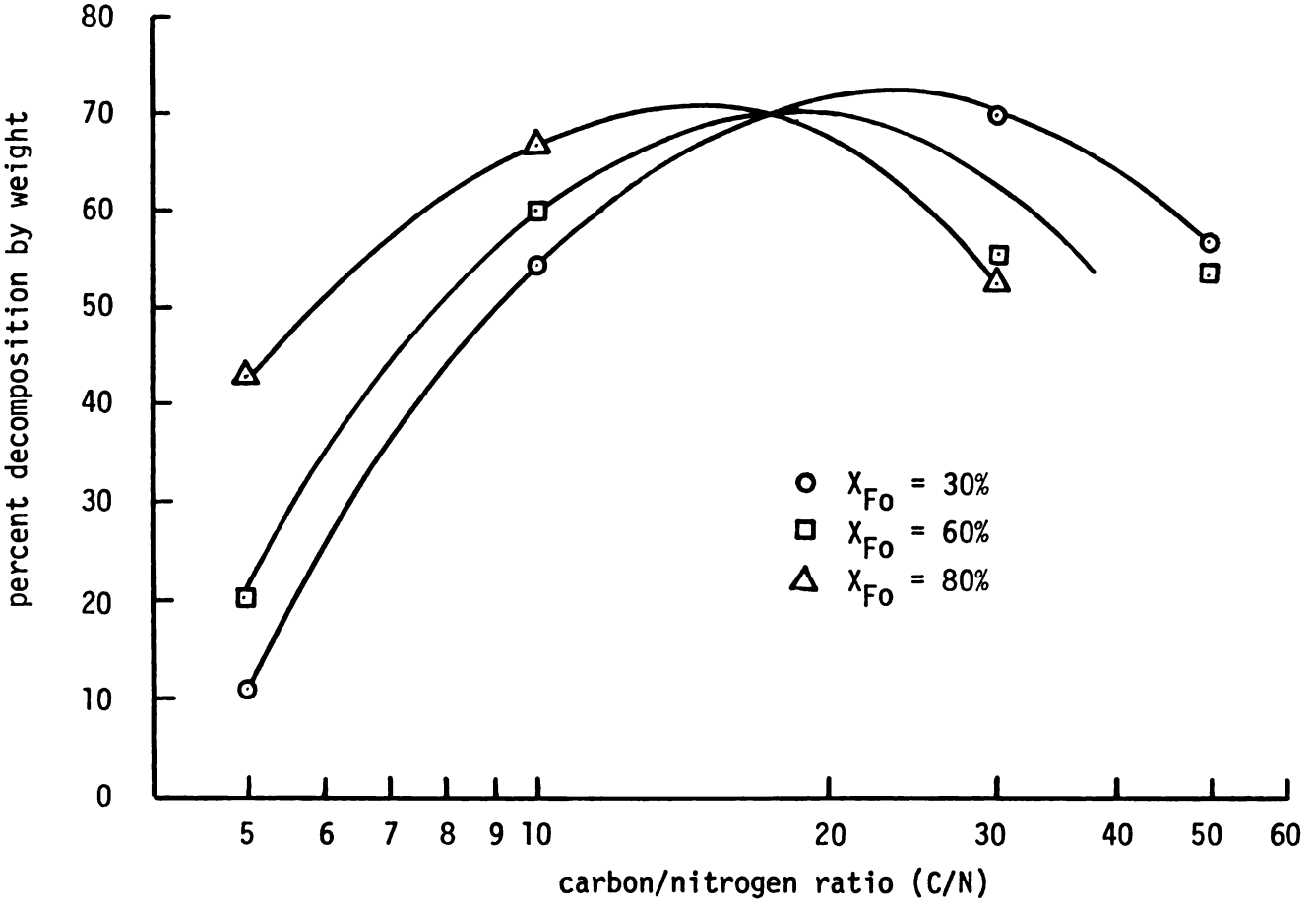


Figure 5.38.--Percent decomposition versus carbon/nitrogen ratio, anaerobic conditions.

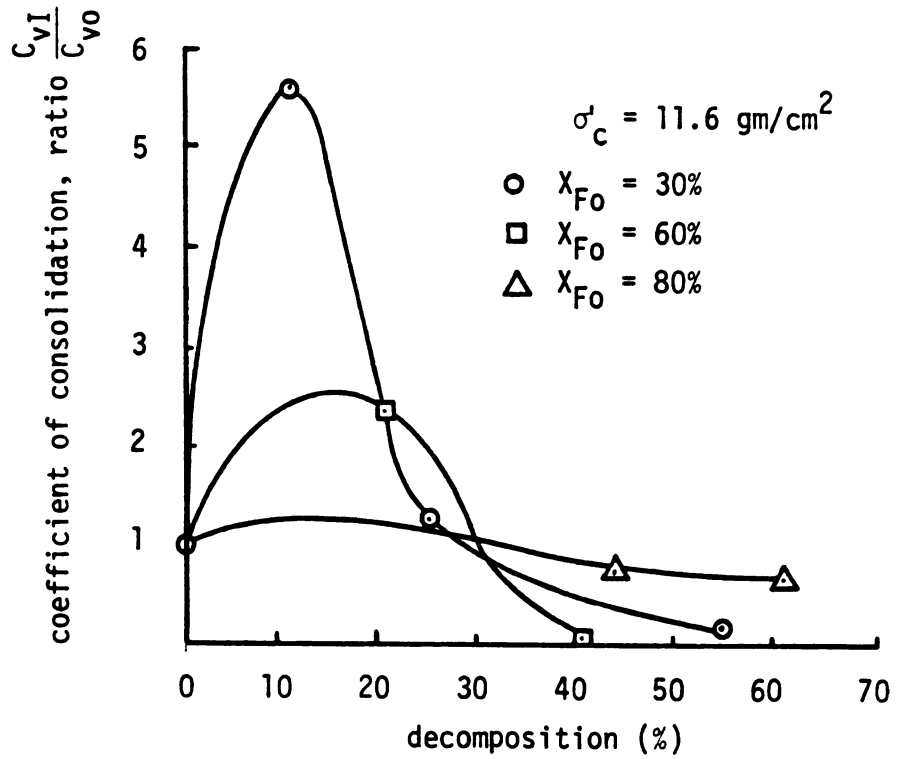
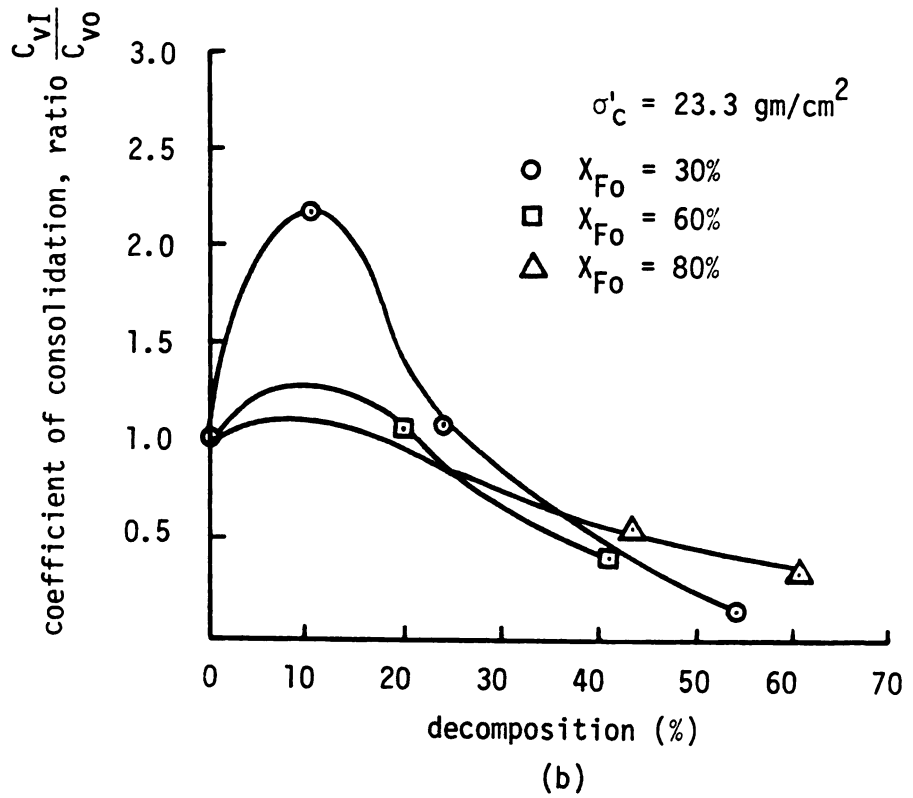
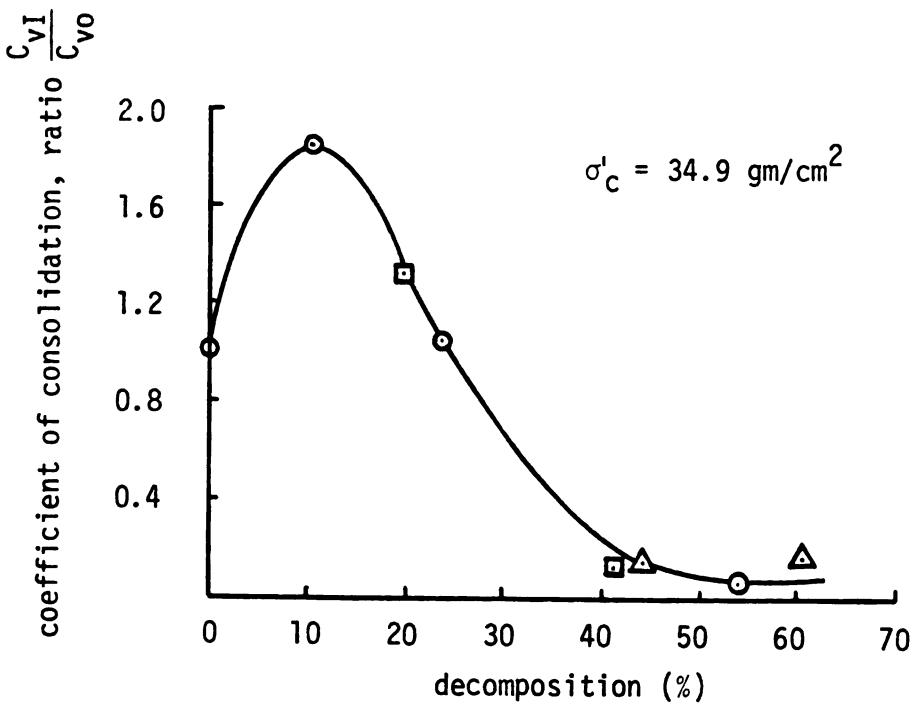


Figure 5.39.--Coefficient of consolidation, ratio of decomposed to initial value, versus percent decomposition, anaerobic conditions. (a) 11.6 gm/cm^2 effective consolidation pressure (σ'_c). (b) 23.3 gm/cm^2 σ'_c. (c) 34.9 gm/cm^2 σ'_c.



(b)



(c)

Figure 5.39.--Continued.

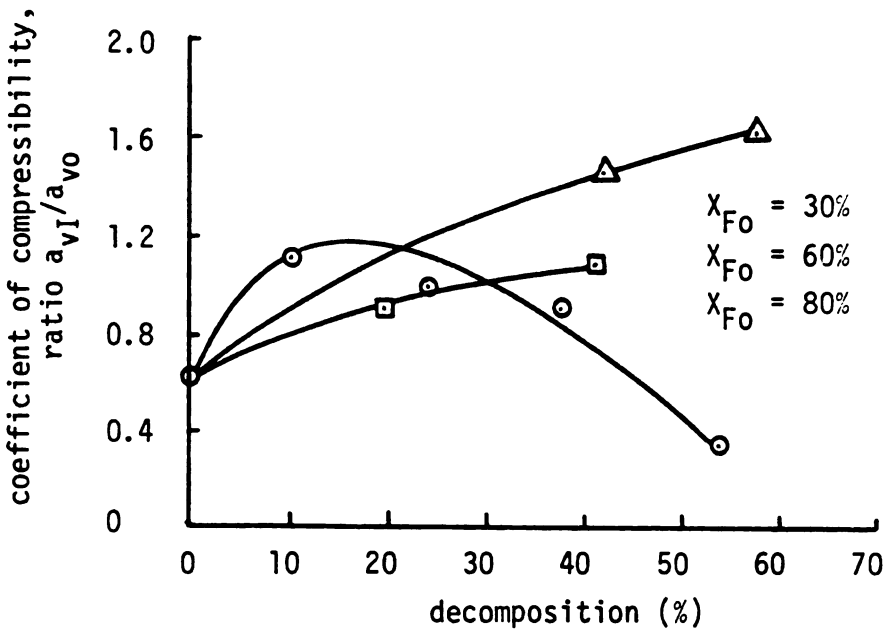


Figure 5.40.--Coefficient of compressibility, ratio of decomposed to initial value, versus percent decomposition, variable C/N ratio, anaerobic conditions.

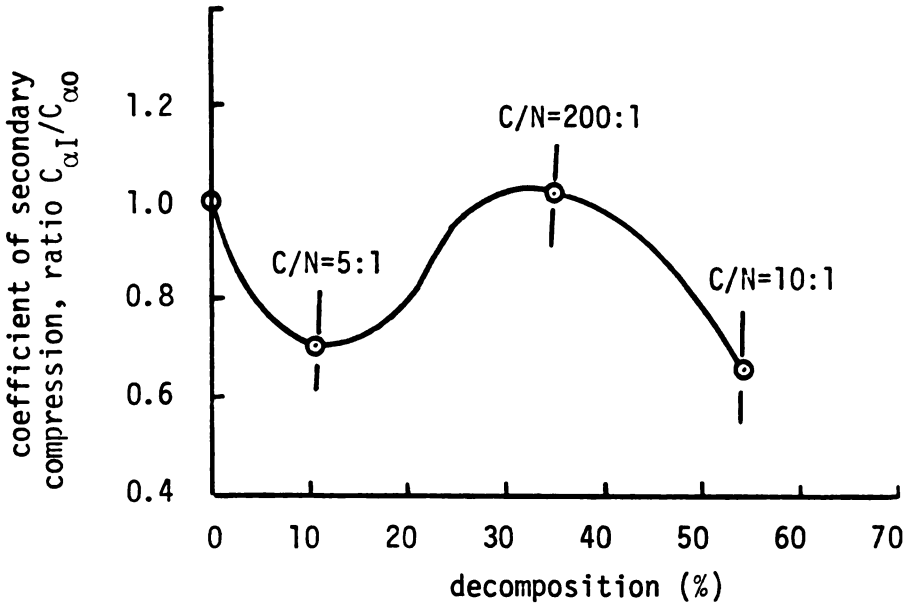


Figure 5.41.--Coefficient of secondary compression, ratio of decomposed to initial value, variable C/N ratio, anaerobic conditions for 30% initial organic content.

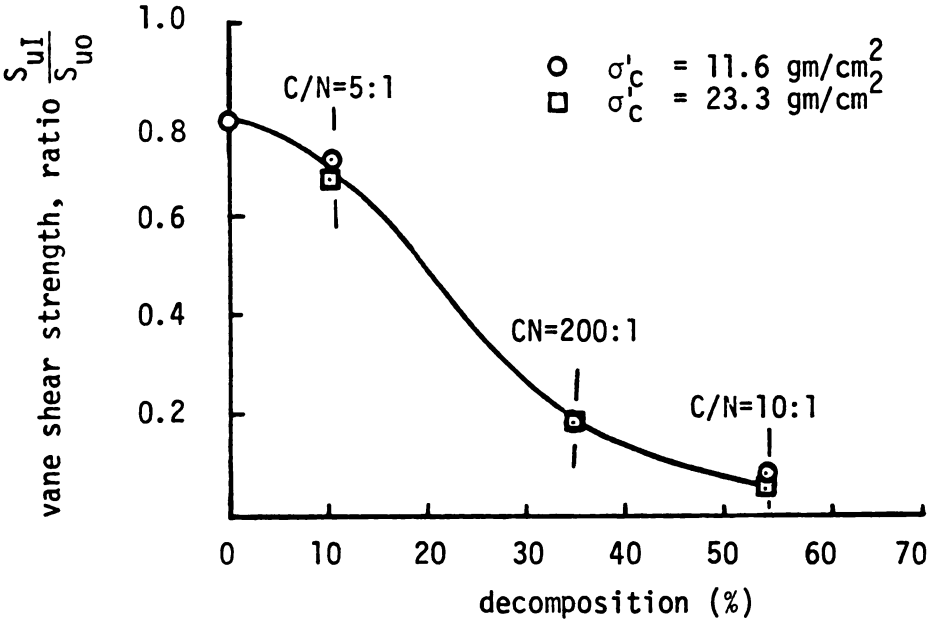


Figure 5.42.--Vane shear strength, ratio of decomposed to initial value, versus percent decomposition, variable C/N ratio, for 30% initial organic content.

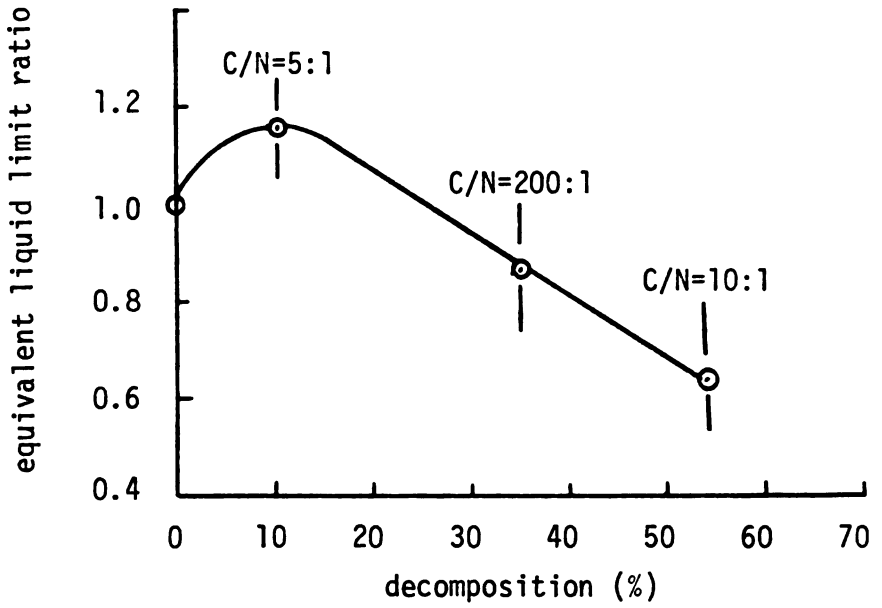


Figure 5.43.--Equivalent liquid limit, ratio of decomposed to initial value, versus percent decomposition variable C/N ratio, anaerobic conditions, for 30% initial organic content.

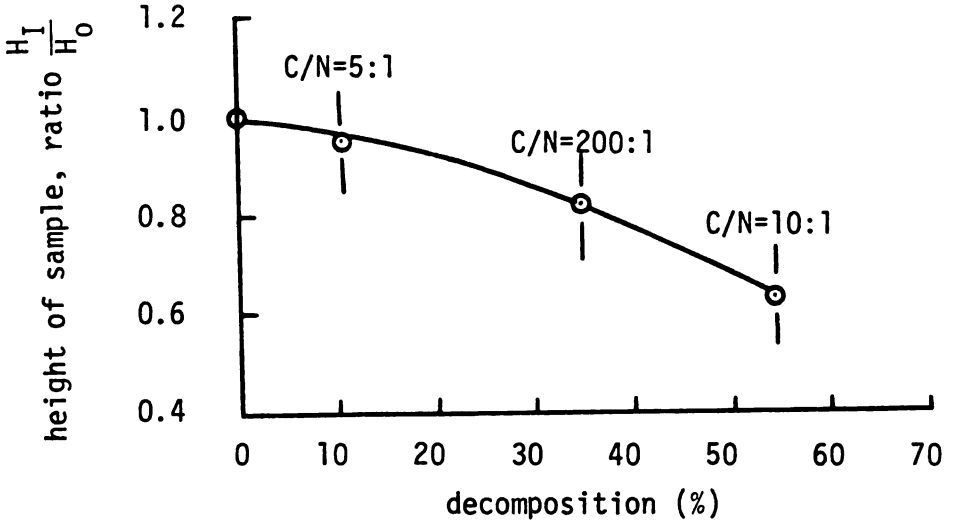


Figure 5.44.--Height of sample, ratio of decomposed to initial value, versus percent decomposition variable C/N ratio, anaerobic conditions, for 30% initial organic content.

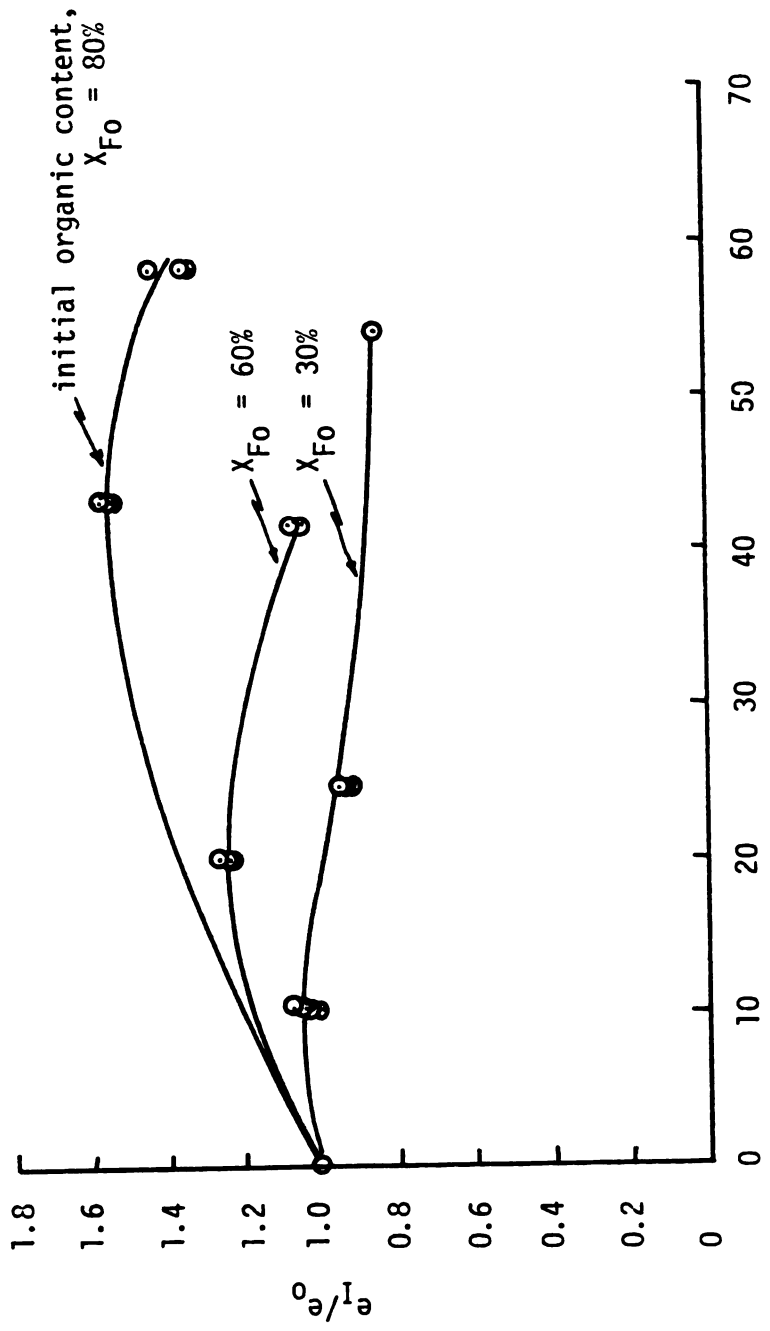


Figure 5.45.--Void ratio, ratio of decomposed to initial value, for stress increments of 5.81 → 11.6 → 23.3 → 34.9 gm/cm^2, under anaerobic conditions.

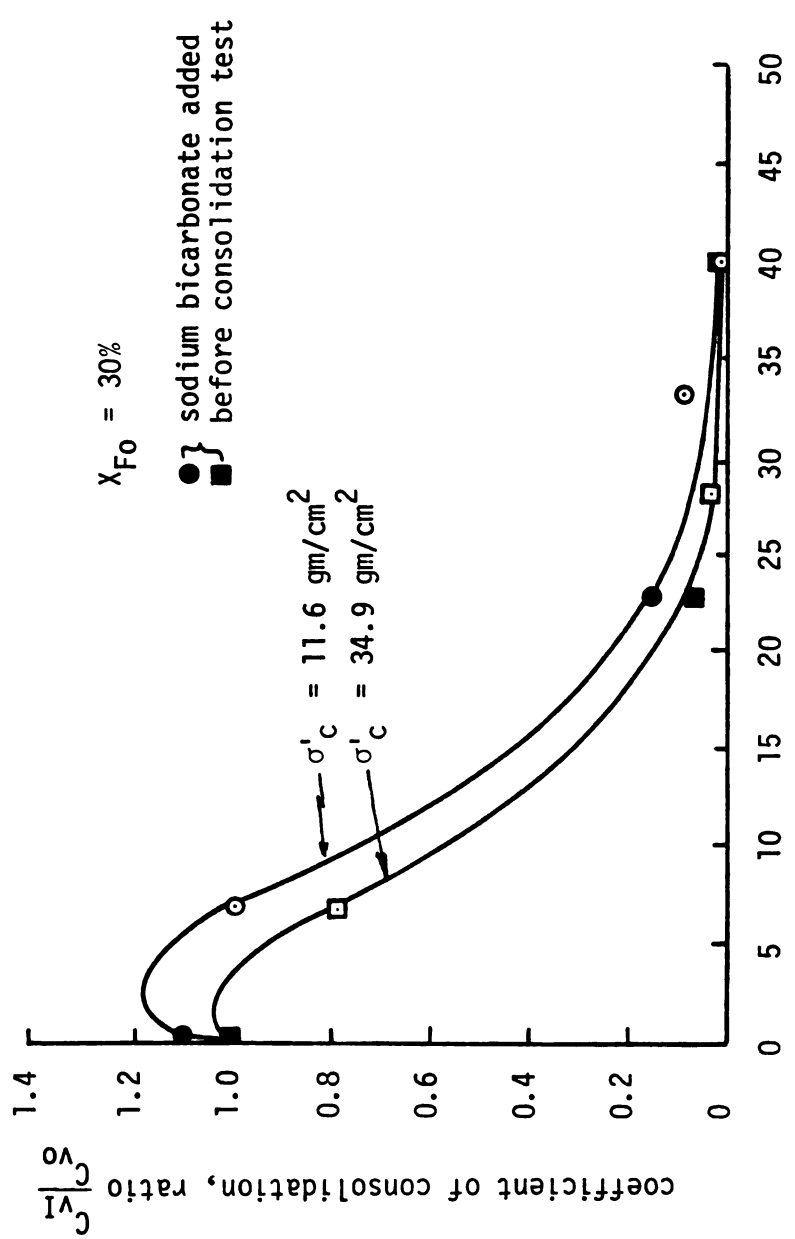


Figure 5.46.--Coefficient of consolidation, ratio of decomposed to initial value, versus decomposition, 30:1 carbon/nitrogen ratio, anaerobic conditions. (a) 30% initial organic content (X_{Fo}). (b) 60% X_{Fo}. (c) 80% X_{Fo}.

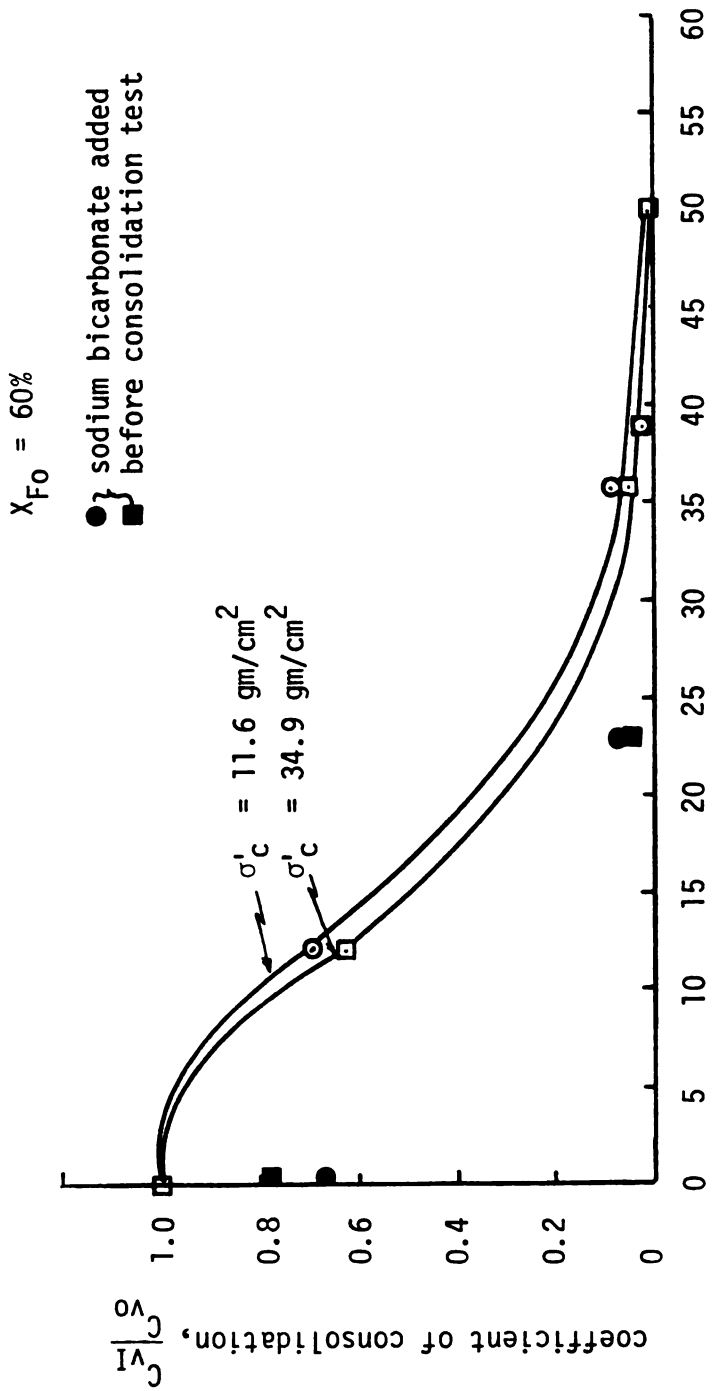


Figure 5.46.--Continued.

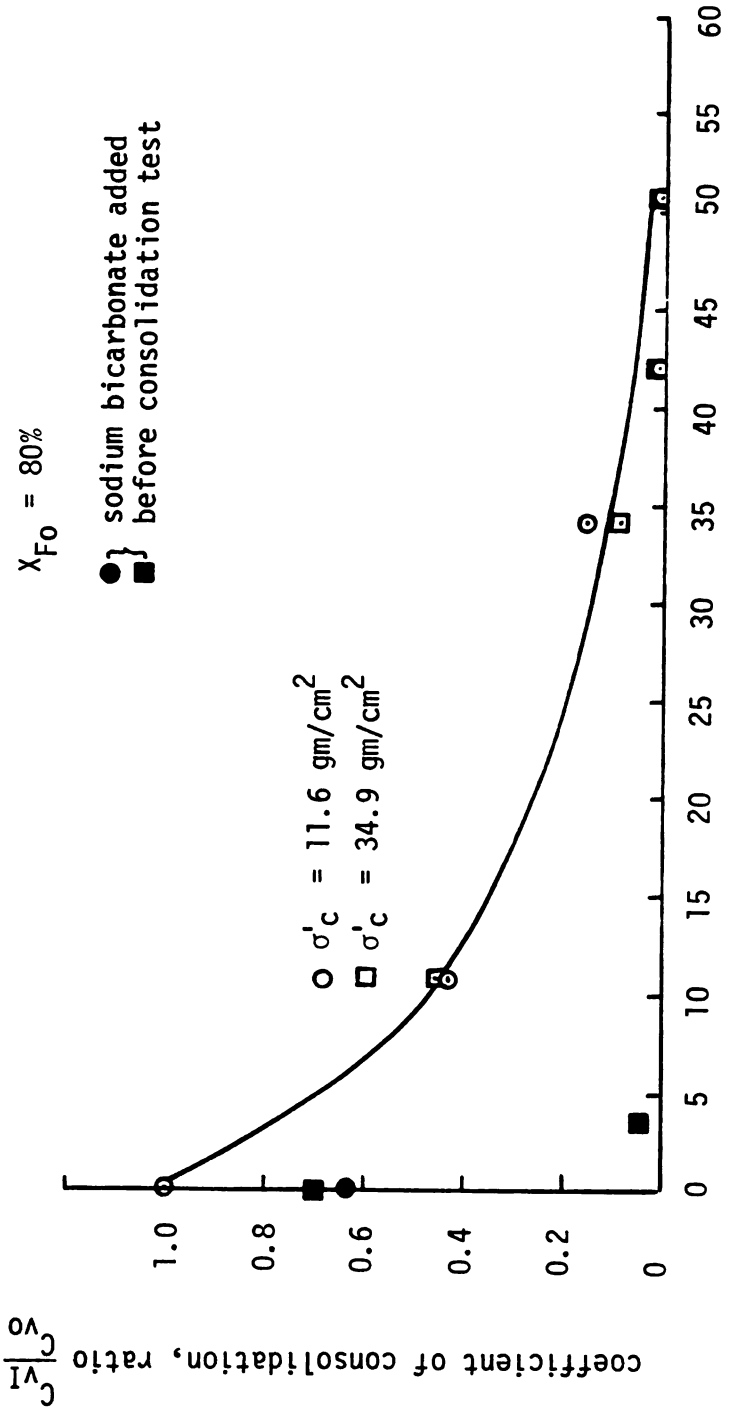


Figure 5.46.--Continued.

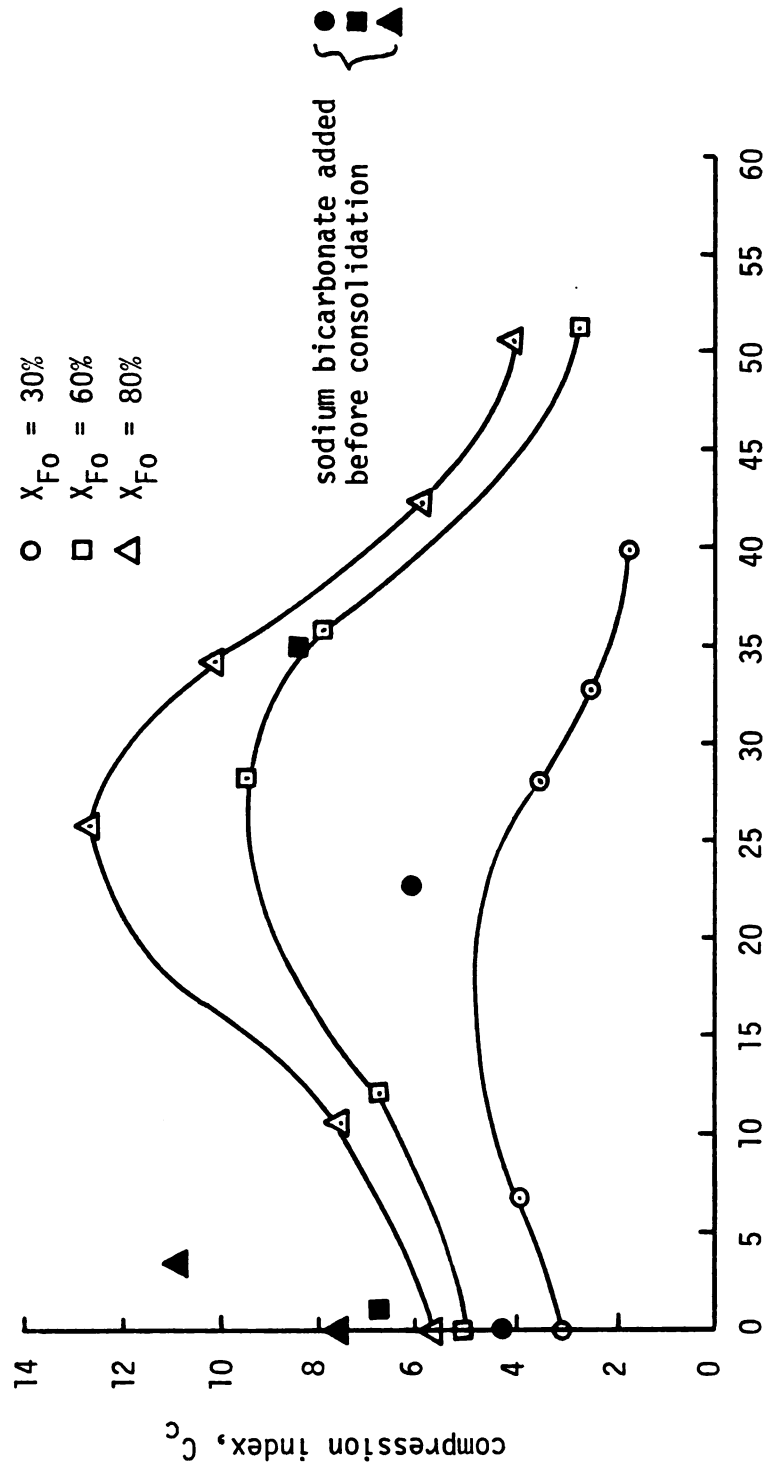


Figure 5.47.--Compression index versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio.

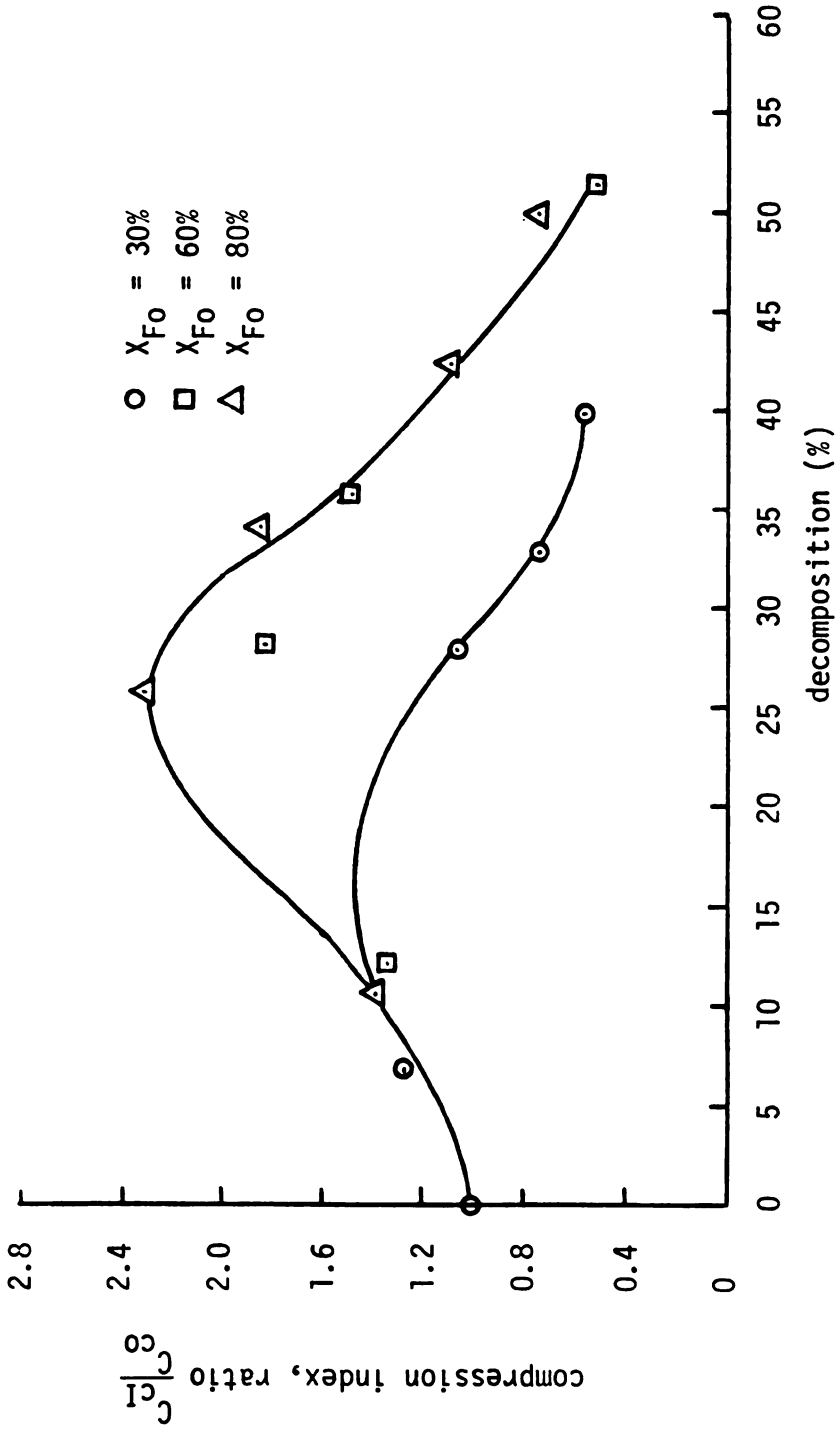


Figure 5.48.--Compression index, ratio of decomposed to initial value, versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio.

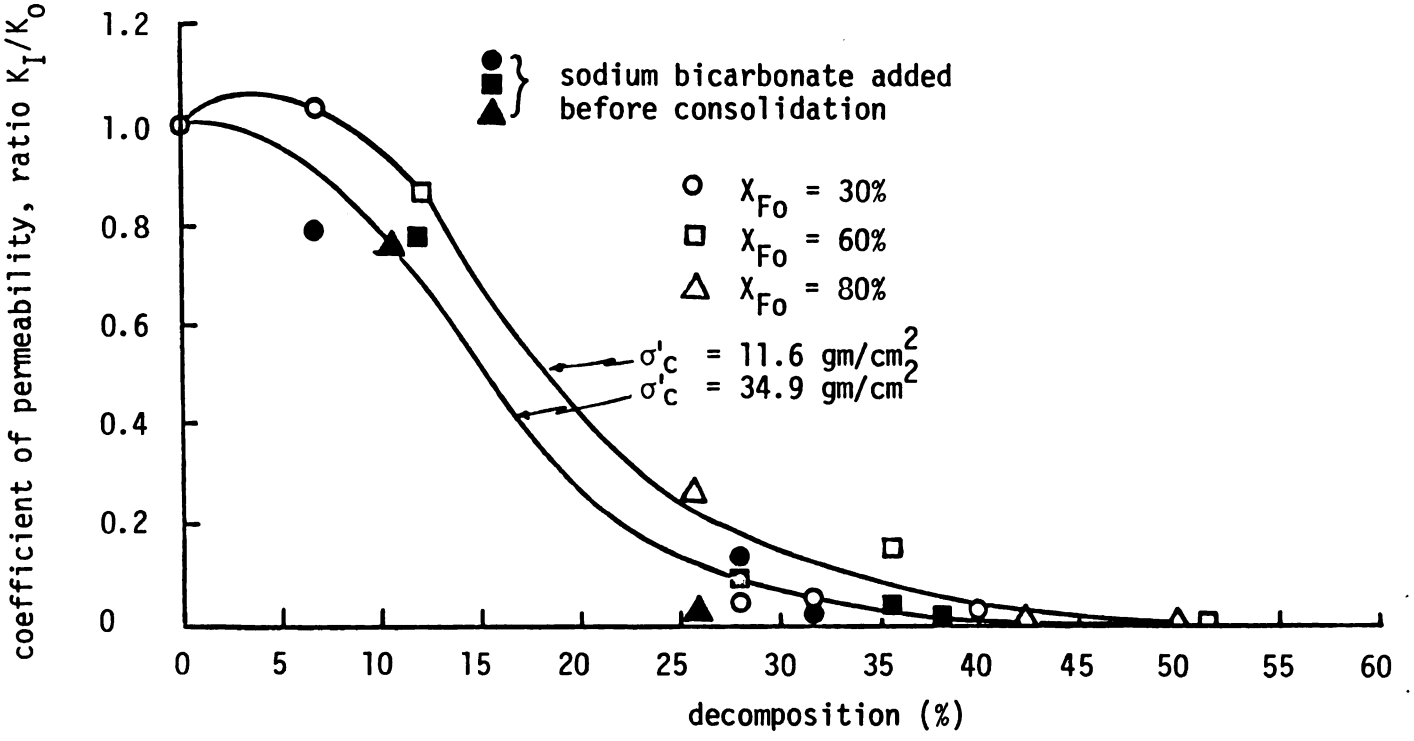


Figure 5.49.--Coefficient of permeability, ratio of decomposed to initial value, versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio.

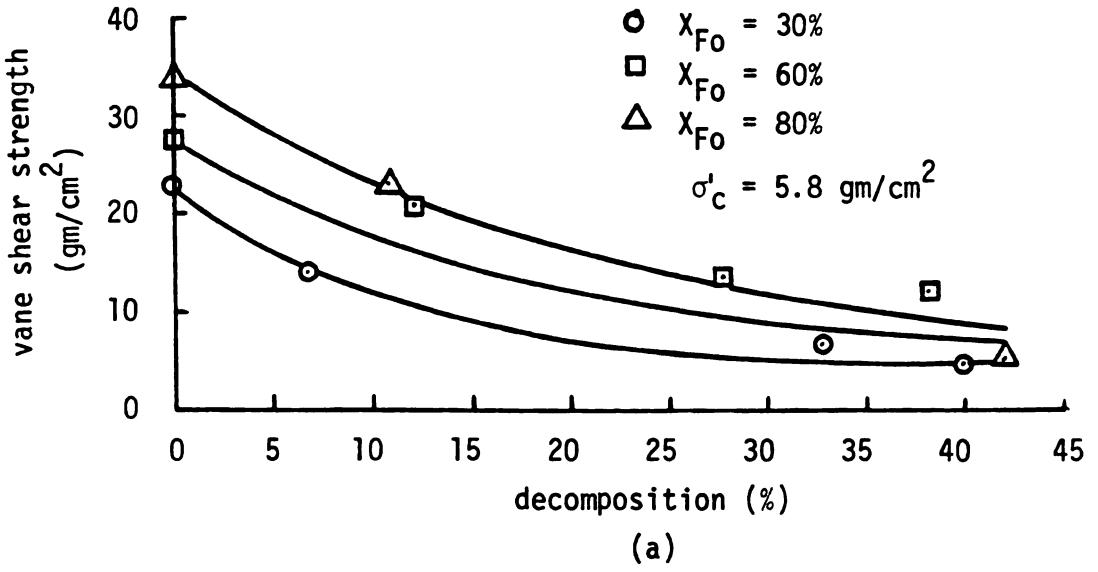
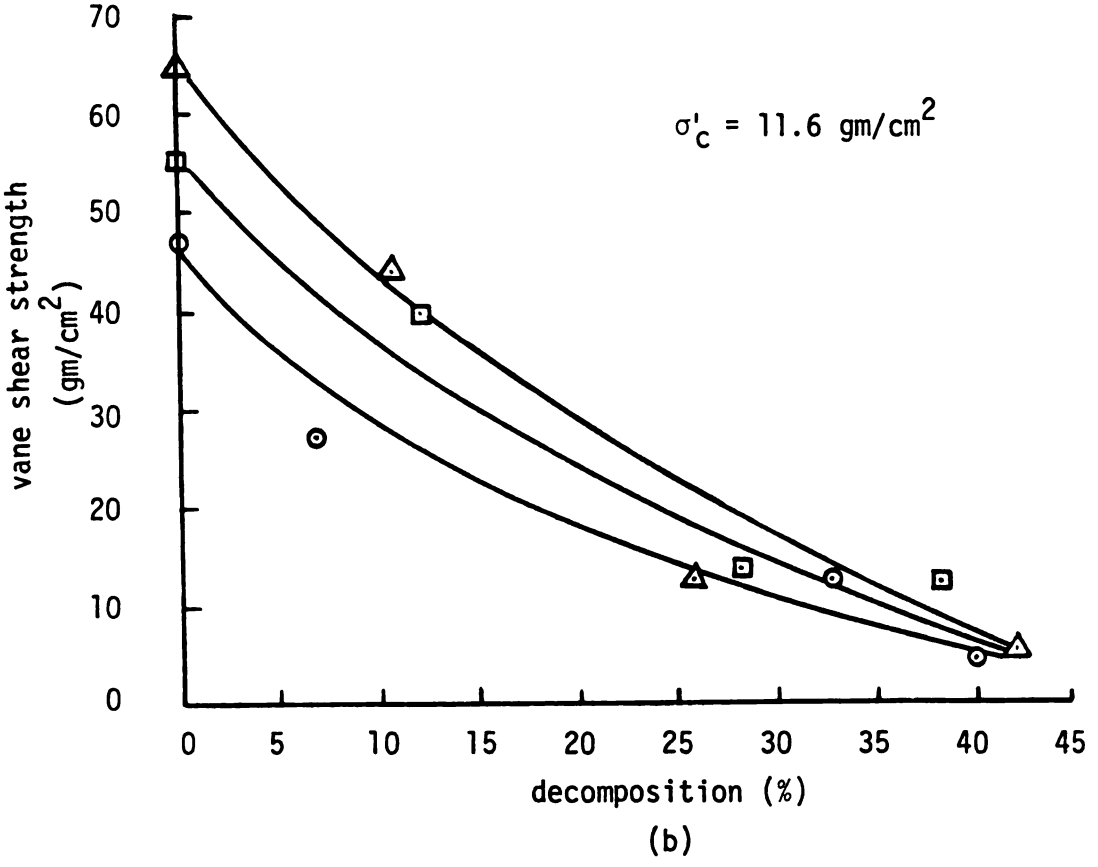


Figure 5.50.--Vane shear strength versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio. (a) 5.8 gm/cm^2 effective consolidation pressure (σ'_c). (b) 11.6 gm/cm^2 σ'_c.



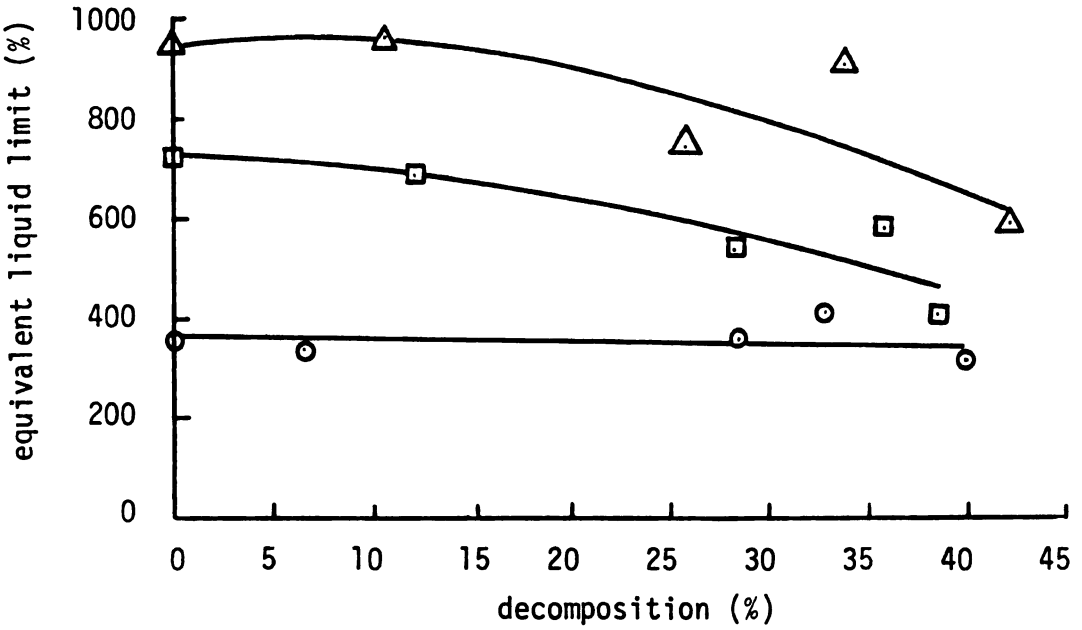


Figure 5.51.--Equivalent liquid limit versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio.

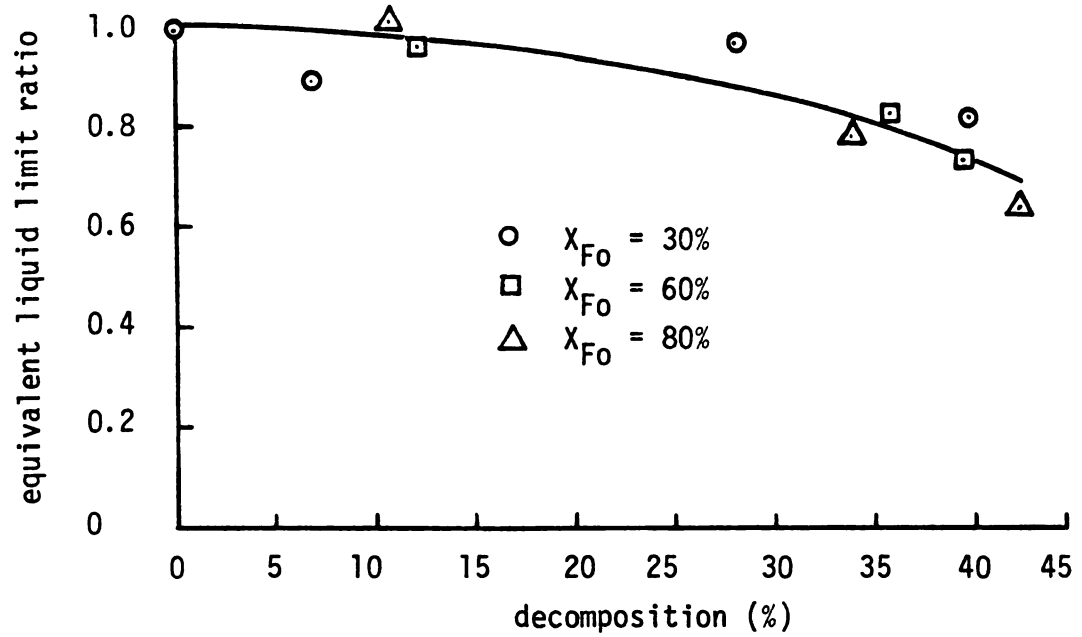


Figure 5.52.--Equivalent liquid limit, ratio of decomposed to initial value, versus percent decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio.

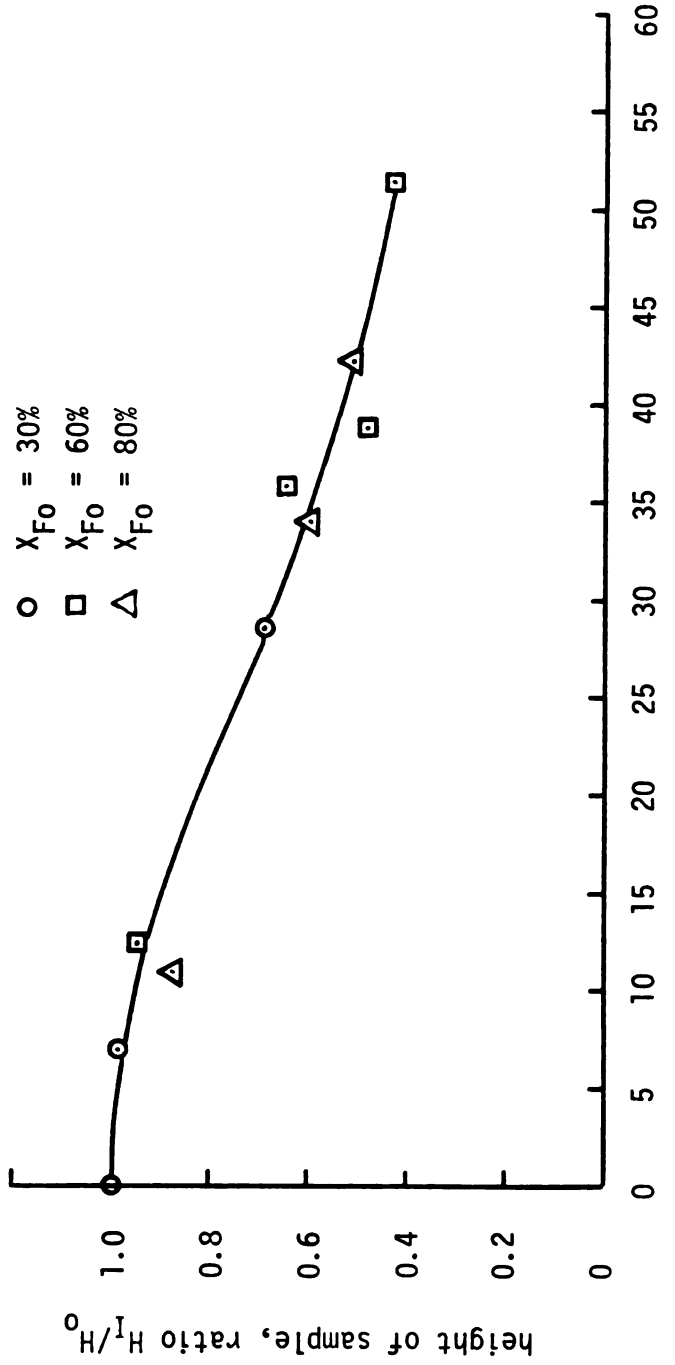


Figure 5.53.--Height of sample, ratio of decomposed to initial value, versus decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio, 34.9 gm/cm^2 effective consolidation pressure.

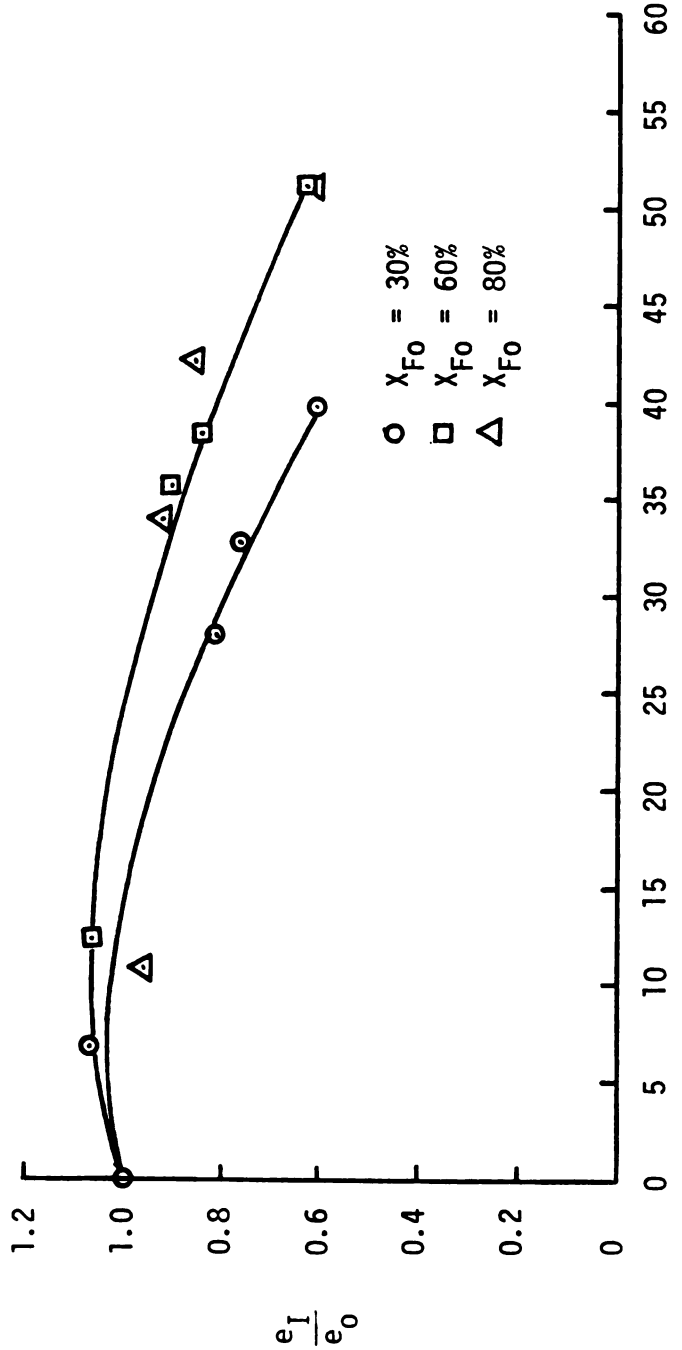


Figure 5.54.--Void ratio, ratio of decomposed to initial value, versus decomposition, anaerobic conditions, 30:1 carbon/nitrogen ratio, 34.9 gm/cm^2 effective consolidation pressure.

CHAPTER VI

ANALYSIS AND DISCUSSION

A. Physical and Chemical Properties of Fibrous Organic Soils

Physical and chemical properties of organic soils have a direct bearing on the behavior of these soil masses during and after construction operations. The determination of relevant physical and chemical properties can be very tedious and involved because of potential decomposition of the organic fraction. Unlike mineral soils whose properties are relatively constant, organic soil properties (chemical or physical) are dynamic in nature and are influenced by the degree of decomposition. Therefore, a distinction must be made between a property (constant) and a parameter (variable) relative to whether a given soil is mineral or organic. Some of the relevant physical properties include: composition, consistency limits, water content, specific gravity. Acidity is the chemical property of organic soils most relevant for engineering purposes.

1. Composition

The framework or structure of a soil mass is composed of minerals and possibly organic solids and voids with either moisture, air, or both occupying the voids. The orientation of particles, contact areas, and distance between particles describes its structure.

In fibrous organic soils this structure is greatly influenced by the organic fraction. Therefore, decomposition of the fibers will result in a breakdown of the soil structure. The consequence of altering the orientation, length, and possibly the diameter of the organic fibers due to microbial activities will definitely affect the physical and chemical properties of these organic soils. As a result an electron microscope was used to monitor the type and extent of microbial attack on fibers which constituted the organic fraction in the test program.

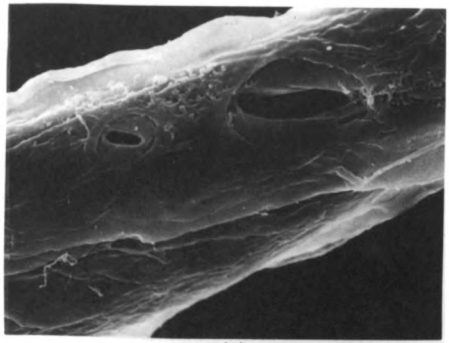
A sample containing cellulose and kaolinite clay was photographed before decomposition, to establish an initial condition (Fig. 6.1.b). A photograph of pure cellulose with no clay was taken, so that a clear view of the fiber was available (Fig. 6.1.a). This sample was seeded with adequate amounts of nutrients (C/N = 5) and micro-organisms (1% dry sample weight). In storage the temperature was controlled so that decomposition would take place in the mesophilic range (35°C). An average degree of decomposition of 80% was attained in a two-month period. A representative sample weight, about 10 gm, was taken to show the effects of decomposition on the organic fibers by means of the electron scanning microscope. The sample was dehydrated for 5 minutes, successively, in ethanol/water concentrations of 25, 50, 75, and 90%. This was followed by four changes of 5 minutes, each in 100% ethanol. The sample was then dried in a sorval critical point drier using CO_2 as the carrier gas. A sample weighing 1.0 gm was then mounted on aluminum stubs with scotch brand double

stick tape and coated with approximatey 200 Å of gold in a film-vacuum sputler coater.

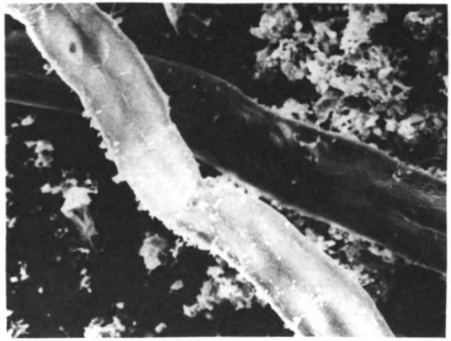
The initial micro-organisms attack on the organic fibers appears as a crack on the fiber surface (Fig. 6.2a). To a large extent decomposition occurs on the inside of the fiber due to the ability of the micro-organisms to maintain high concentrations of intermediate hydrolysis products in the small cavities (Fig. 6.2.b). A cavity along the length of the fiber and a rough surface brought about by decomposition is shown in Fig. 6.2.c. What started as a crack in Fig. 6.2.a and subsequently a cavity in Fig. 6.2.b and Fig. 6.2.c, has now resulted in a complete split of the fiber (Fig. 6.2.d). The consequences of this process must relate to a reduction in undrained shear strength with decomposition.

When the micro-organism types responsible for decomposition of fibrous organic materials are known, nutritional requirements needed to increase or slow down decomposition could be predicted. Round shaped bacteria are shown in Fig. 6.3. The star shaped configuration appears to be either a colony of rod shaped bacteria or some form of crystals with unknown identification.

A cellulose fiber in an advanced stage of decomposition, showing loss of structural integrity, is shown in Fig. 6.3. Both exterior and interior degradation have resulted in a splitting of the fiber and shows that the fiber is made of many strands. A comparison with Fig. 1 illustrates why a change in the engineering properties can be expected as a result of decomposition.

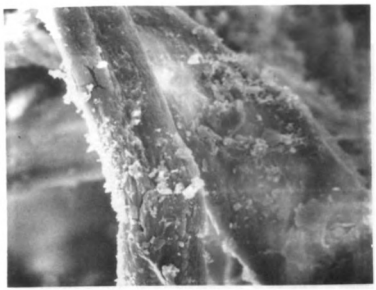


(a) 2000 x

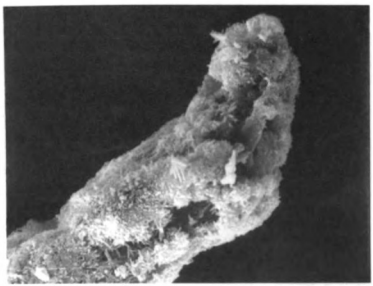


(b) 1000 x

Figure 6.1.--Electron scanning microscope photographs. (a) Undecomposed cellulose fiber. (b) Undecomposed cellulose with Kaolinite particles.

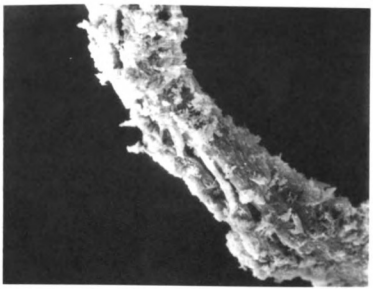


(a) 1000 x

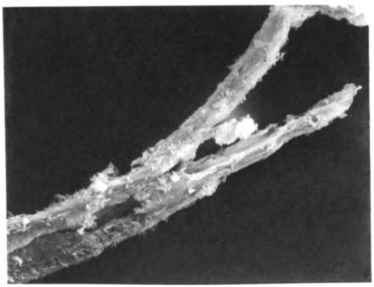


(b) 2000 x

Figure 6.2.--Electron scanning microscope photographs of partially decomposed fibers. (a) Nutrient, bacteria, and a crack. (b) Cavities inside the fiber. (c) Cavity along the length of the fiber. (d) A complete split of the fiber. (e) Advanced stage of decomposition with loss of structural integrity.



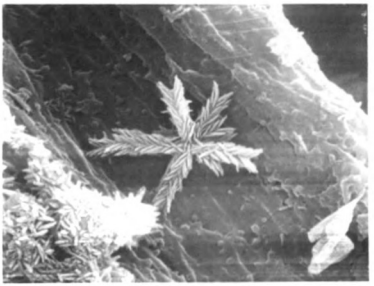
(c) 1000 x



(d) 1000 x

Figure 6.2.--Continued.

Figure 6.2.--Continued. (e) 1000 x



5000 x

Figure 6.3.--The exposed interior of a decomposed fiber is shown. Round shaped bacteria are visible. The star shaped configuration appears to be either a colony of rod shaped bacteria or some form of crystals with unknown identification.

2. Consistency Limits

The liquid limit and plastic limits have been widely used for soil identification and classification. The shrinkage limit is useful in certain geographical areas where soils undergo large volume changes (Bowles, 1970). The organic content of a given soil influences the consistency limits (Charlie, 1975). Unfortunately, conventional methods used for mineral soils have limited application when fibers in organic soils interfere with standard test methods. Consistent results were not obtainable, using the standard liquid limit test (ASTM D423-66) on samples containing 30, 60, and 80% fibrous organic matter. The fibrous nature of the samples prevented separation of the sample with the grooving tool, without tearing the sides. Casagrande (1932), based on research on the liquid limit of soils, suggested that the liquid limit is a measure of the shear strength at some water content. He concluded that each blow to close the standard groove corresponds to a shear strength of about 1.0 gm/cm^2. This shear strength provided the basis for the so-called equivalent liquid limit, used in the test program. The shear strength was determined using a miniature vane apparatus (Fig. 4.4). The incremental consolidation pressures made it possible to determine the water content corresponding to 25 gm/cm^2 shear strength. This water content was used as the equivalent liquid limit.

Decomposition of the organic fiber resulted in an initial increase of the equivalent liquid limit, then a decrease when the percent decomposition exceeded about 25% for a variable C/N ratio (Fig. 5.43). Careful examination of this curve revealed that a linear

relationship appears to exist between decomposition and the ratio of final to initial equivalent liquid limit ($\frac{LL_I}{LL_o}$), when the degree of decomposition is greater than 10%. It would seem reasonable to assume that ($\frac{LL_I}{LL_o}$) will continue to decrease with greater decomposition until a limiting value is reached. The reasoning is that the moisture holding capacity of soils increases with increasing organic contents (MacFarlane, 1969). Consequently a decrease in the organic content due to biological activities should result in a decrease in the liquid limit. Determination of the plastic and shrinkage limits were not possible, hence they were discontinued. This fact illustrates the need for developing new techniques for determining these limits.

3. Moisture Content

Organic soils differ from mineral soils in many aspects, one of which is their unusually high water retention capacity. This higher natural water content has an influence on other physical and mechanical properties.

One aspect of organic soils is their potential decomposition and the changes that might occur in their various properties. An initial increase followed by a sharp decrease was observed in their moisture content with decomposition (Fig. 6.4). For a consolidation pressure increment of 11.6 to 23.3 gm/cm^2 and a carbon/nitrogen ratio of 30:1, it was determined that higher moisture contents correspond to higher organic contents irrespective of the average degree of decomposition. Using data in Appendix B the different consolidation

pressure increments versus organic content for the various C/N ratios can be easily plotted. Careful examination of Fig. 6.4 shows the tendency of the 30, 60, and 80% organic content samples of asymptotically approaching the kaolinite equivalent moisture content. The term equivalent moisture content refers to the water content plus nutrients in the sample.

4. Specific Gravity

The specific gravity of a given soil is essential for void-ratio calculations and the coefficient of compression. Errors involved in its determination may result in over- or underestimating the amount of compression in a given soil. Present methods of determining the specific gravity for mineral soils is a straight forward matter. However, in organic soils the error involved in its determination could be 18% (MacFarlane, 1969). This fact was apparent at the outset of the research project. A new method was required so that some, if not all, of the error involved could be eliminated. The new procedure was developed and covered in section 4-C. The error involved in specific gravity determination using the conventional method (MacFarlane, 1969) comes from two sources. They include:

1. MacFarlane assumes a linear relationship between the specific gravity and ash content. This was shown to be incorrect, see Equation 4-23,

2. The assumption that all organic matter has a specific gravity of 1.5 is an oversimplification of the actual value. The specific gravity of organic materials vary from 1.0 to 2.0 (MacFarlane, 1969),

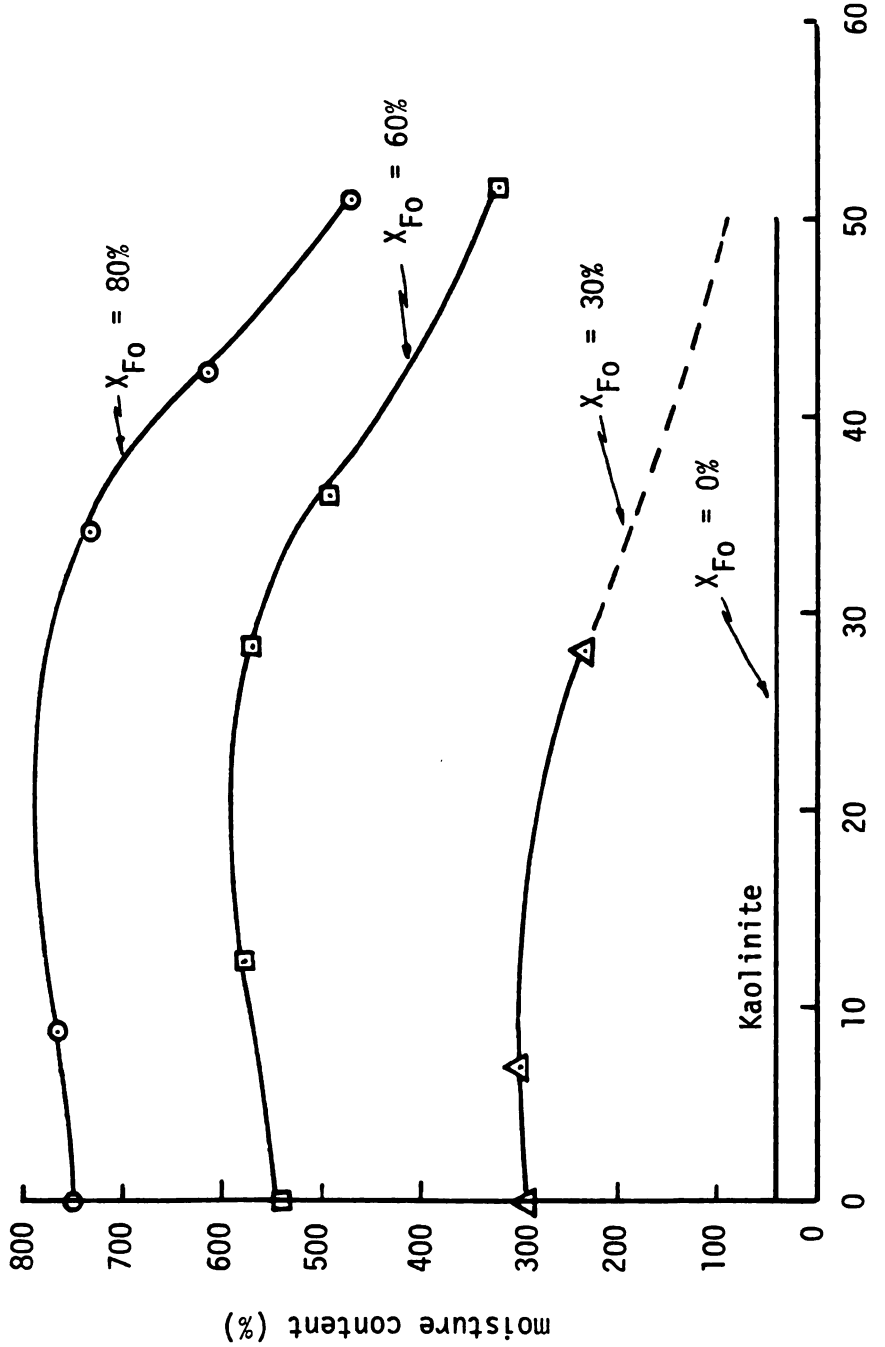


Figure 6.4.--Moisture content versus percent decomposition for an effective consolidation pressure σ'_c = 23.3 gm/cm^2, anaerobic conditions, and 30:1 carbon/nitrogen ratio.

3. Since present methods of organic content determination could err by up to 15% (MacFarlane, 1969), this would introduce another source of error. A new procedure, outlined in section 4-A, has reduced this error to about 1%.

Elimination of these errors has made possible more accurate data collection throughout the test program. Since cellulose fiber (G_s = 1.5) and kaolinite clay (G_s = 2.7) were used in the makeup of the organic soil samples involved in the laboratory testing program, it is possible to compare the conventional and the newly developed method for specific gravity determination. The region of maximum error is shown in Fig. 6.5 with a maximum difference of 0.18 in the specific gravity noted for an organic content of 50%.

5. Hydrogen Ion Concentration

The pH level controls the rate of decomposition in organic soils. The reason is that certain micro-organisms cannot survive a drastic change in pH, for example, methanogenic bacteria required a pH range between 6.6 to 7.4 (McCarty, 1964). Knowing that anaerobic degradation is a two-stage process, the acid phase and methane phase would indicate a desirable pH level of 6.6 to 7.4. Hence, the acid formers, i.e., the micro-organisms responsible for converting organic matter into volatile acids, would also survive in that pH range.

In the test program the pH was maintained close to 7.0 so as to insure a smooth progression of the anaerobic decomposition. This was accomplished by adding sodium bicarbonate every two weeks to bring the pH level back to the desirable level. The pH balancing was very critical because it made the difference between success and failure

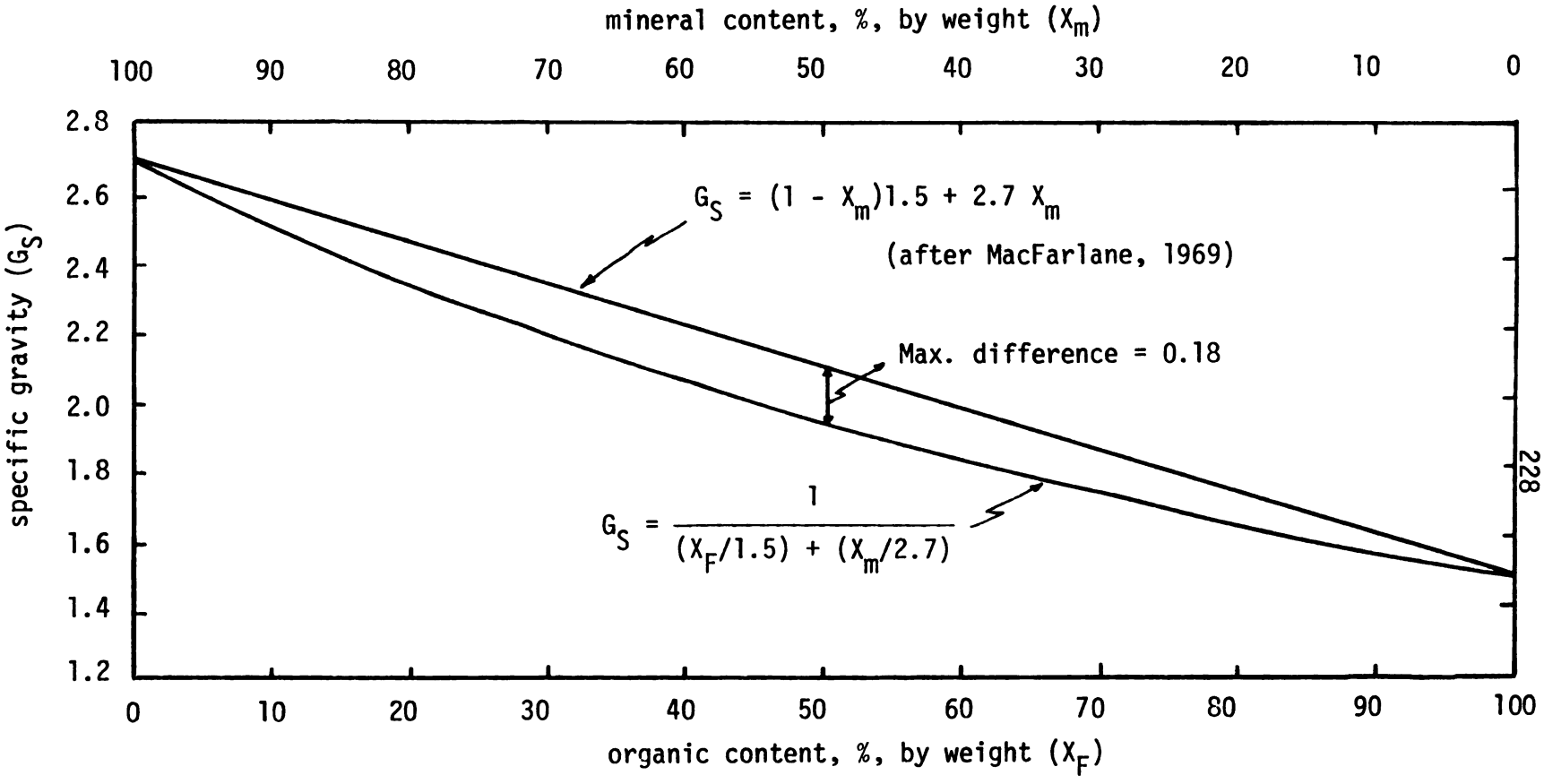


Figure 6.5.--Specific gravity of organic soils versus organic content, conventional and corrected method.

of the decomposition process. The amount of sodium bicarbonate needed to bring the pH from one level to another for a given mass depends on the degree of decomposition (Fig. 6.6). Twenty grams of sodium bicarbonate was used to raise the pH from 6.3 to 7.0 after 15 days of decomposition, whereas only 15 grams was required to raise the pH from 5.6 to 7.0 after 30 days of decomposition. Data for other organic contents and carbon/nitrogen ratios are summarized in Appendix E.

As a result of the drop in pH due to the production of volatile acids by micro-organisms, it seemed reasonable to assume that a change in the bonding forces between particles would have an effect on some, if not all, of the engineering properties of these organic samples. A plot of vane shear strength vs. pH showed that this, indeed, was the case (Fig. 5.26). This figure shows that there is a large increase in shear strength as the pH approaches 7.0. The increase in shear strength may be due to the larger attraction forces between particles at the neutral pH of 7.0. This change in attractive forces will alter the coefficient of consolidation and consequently will give a denser material for the same consolidation pressure (Low, 1975).

B. Decomposition of Organic Soils

The mechanism by which organic matter decomposes is a very complex and involved process. One area of concern to the geotechnical engineer dealing with organic soils, is the potential for decomposition of these soils. Other questions of interest include such things as,

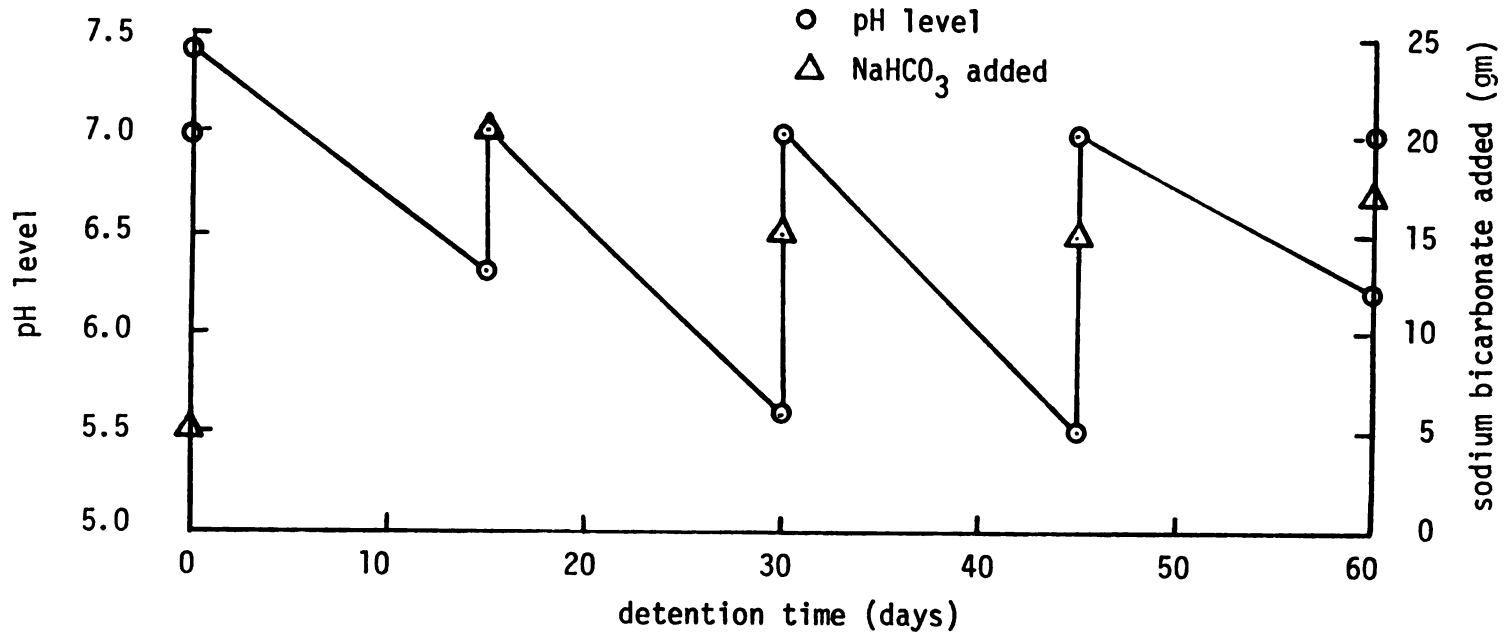


Figure 6.6.--pH versus detention time, 30 percent organic content, 10:1 carbon/ nitrogen ratio, anaerobic conditions.

what C/N ratio is required for optimum decomposition, what fraction of the organic solids will disappear during the production of new micro-organism cells, and finally how to measure decomposition. In this section an attempt is made to answer these questions.

1. Optimum C/N Ratio, Aerobic vs. Anaerobic

All micro-organisms must have a mimimum supply of all elements of which their cellular matter is composed (Table 2.2) to keep on reproducing and thus bring about decomposition. The amounts required vary from element to element and at a somewhat constant ratio of one to another. Growth is limited by that element which is present in less than the required concentration. The balance of nutrients is especially important as far as those required in large quantities (carbon or nitrogen). This is why the C/N ratio is such an important parameter in the degradation of organic matter. In contrast to what has been reported in the literature, the carbon/nitrogen ratio is only one of the many important parameters necessary for the decomposition process. The amount of phosphorus, magnesium, calcium, and sodium in relative proportions to nitrogen can very well be the difference between success and failure of a decomposition process. The optimum range of C/N ratios for samples containing 30, 60, and 80% organic matter (cellulose) by weight tested under aerobic conditions was close to 30, 22, and 19, respectively as shown in Fig. 5.31. The implication is that high concentrations of nutrients will slow down the decomposition process. This may be explained on the basis that

certain nutrients, e.g. ammonia and ferric cloride are toxic to micro-organisms in high concentrations (McCarty, 1964). Low concentrations of nutrients also result in a low rate of decomposition. Less nutrients reduce the production of microbial cells, hence less microbial metabolism and therefore less degradation of organic matter. A final observation is that a lower organic content (higher mineral content) results in less decomposition, i.e., the higher the organic content, the higher the rate of decomposition. With higher organic contents and materials with about the same particle size distribution, there is more surface area on which the micro-organisms can grow, hence the higher decomposition rate.

A second set of samples containing 30, 60, and 80% cellulose (by weight) tested under anaerobic conditions gave optimum C/N ratios of 24, 18.5, and 15, respectively, as shown in Fig. 5.38. The higher nutrient concentrations resulted in lower rates of decomposition, the same as for aerobic samples. Unlike the aerobic samples, the extent of toxicity was more pronounced. The pH level is more important as an environmental factor in anaerobic as compared to aerobic processes and could be the reason behind these differences. Another reason could be the fact that different micro-organisms are involved in aerobic vs. anaerobic processes. Some micro-organisms are more sensitive to toxicity and less adaptable to difficult environments. Note that Fig. 5.38 shows that the maximum degree of decomposition, irrespective of organic content, is considerably less than that of the aerobic sample and can be taken as a constant. This was not the case

for aerobic samples and may be related to cell yield and decay. More research is needed to explain this difference. A major difference between the aerobic and anaerobic decomposition processes is that a constant extent of decomposition can be produced anaerobically by selecting a C/N = 27. Other nutrients must be included as described in section 3-B.2.

2. Toxicity

Toxicity refers to the possible inhibition of micro-organism growth in the decomposition process. Decomposition rates are influenced by it as shown in Figs. 5.31 and 5.38. Unfortunately, there is no measure of toxicity except some highly presumptive ranges for different nutrient types. These ranges are highly descriptive as outlined in section 2-B.4. In certain situations it is desirable to have some quantitative measure of toxicity and its effect on the decomposition process. It appeared appropriate to introduce a new definition which quantitatively describes toxicity. This definition states that the optimum percent decomposition, corresponding to an optimum C/N ratio, is toxicity free. Hence, a C/N ratio less than optimum will correspond to a decline in percent decomposition due to toxicity, with a C/N ratio greater than optimum will correspond to a decline in decomposition caused by nutritional deficiencies. This permits a toxic growth factor to be defined as one minus the ratio of percent decomposition, corresponding to the C/N ratio, less than optimum divided by percent decomposition corresponding to optimum C/N ratio. A deficient growth factor is defined as one minus the ratio of a percent

decomposition corresponding to C/N greater than optimum to that of optimum. A plot of the growth factors is shown for the aerobic decomposition process in Fig. 6.7. A second plot for the anaerobic process is shown in Fig. 6.8. A comparison of these two figures reveals that a nutritional deficiency has a greater effect on anaerobic as compared to aerobic micro-organisms. On the other hand, the effect of organic content is more pronounced in the aerobic samples than the anaerobic. Finally, the range of optimal C/N ratios for aerobic samples is much wider as compared to anaerobic samples. These facts appear to give us a clue as to the tolerance of the micro-organisms to environmental changes.

3. Cell Yield

The cell yield of a decomposing material was defined as the ratio of organic mass used in the production of new microbial cells to the degraded mass of the organic material. A mathematical model, developed by McCarty (1969), permits calculation of the cell yield of a given chemostat. This model predicts the cell yield expected for bacteria if there is no cell decay or use of substrate for maintenance energy. It can be considered an upper limit for the actual cell yield, especially for long time periods as was the case in this test program.

a. Aerobic cell yield.--Actual aerobic cell yields should be less than that predicted by McCarty's model due to the large amount of fungel growth, anaerobic zones, and cell decay or use of substrate

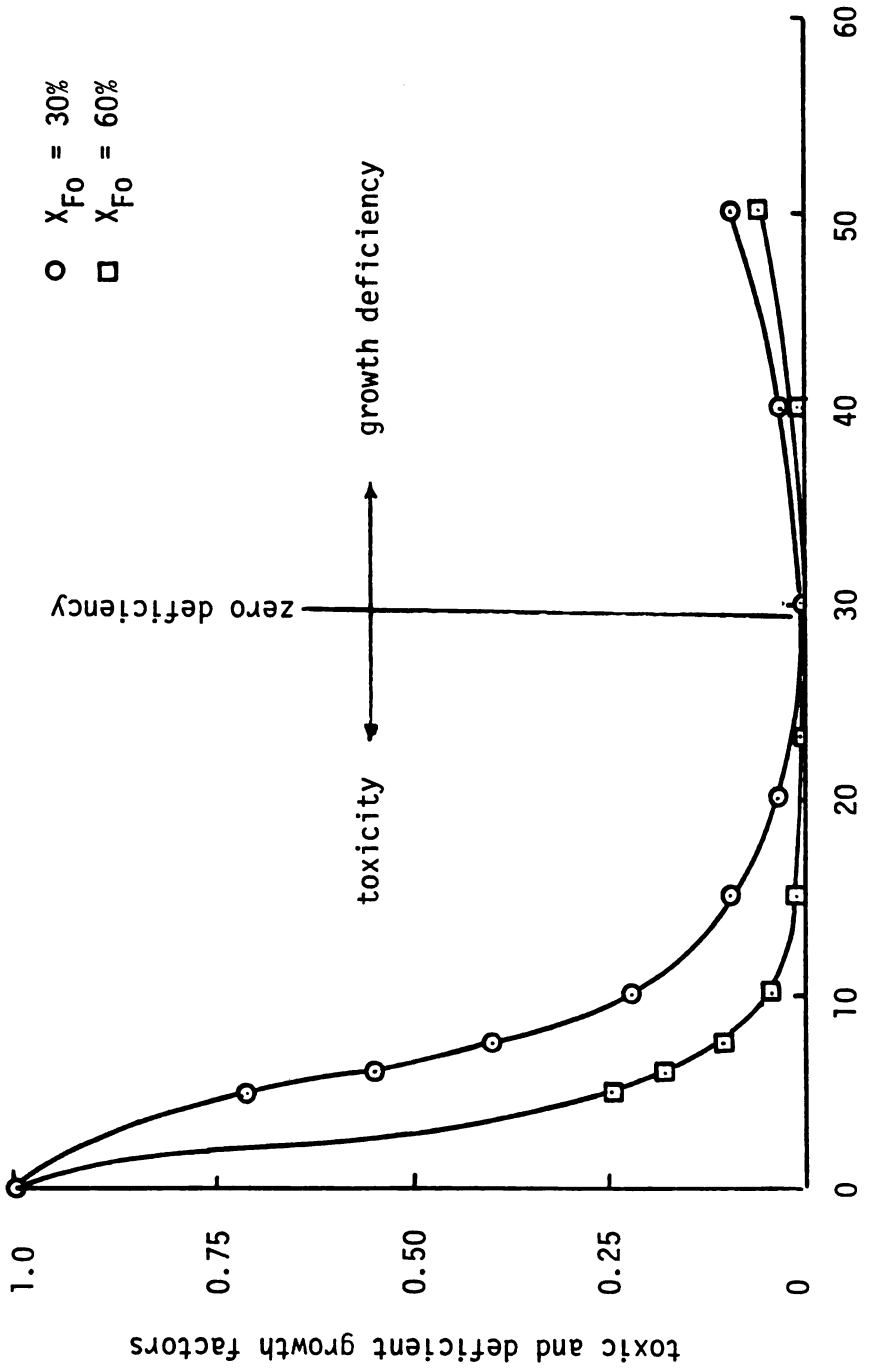


Figure 6.7.--Toxic and deficient growth factors versus carbon/nitrogen ratio, aerobic conditions.

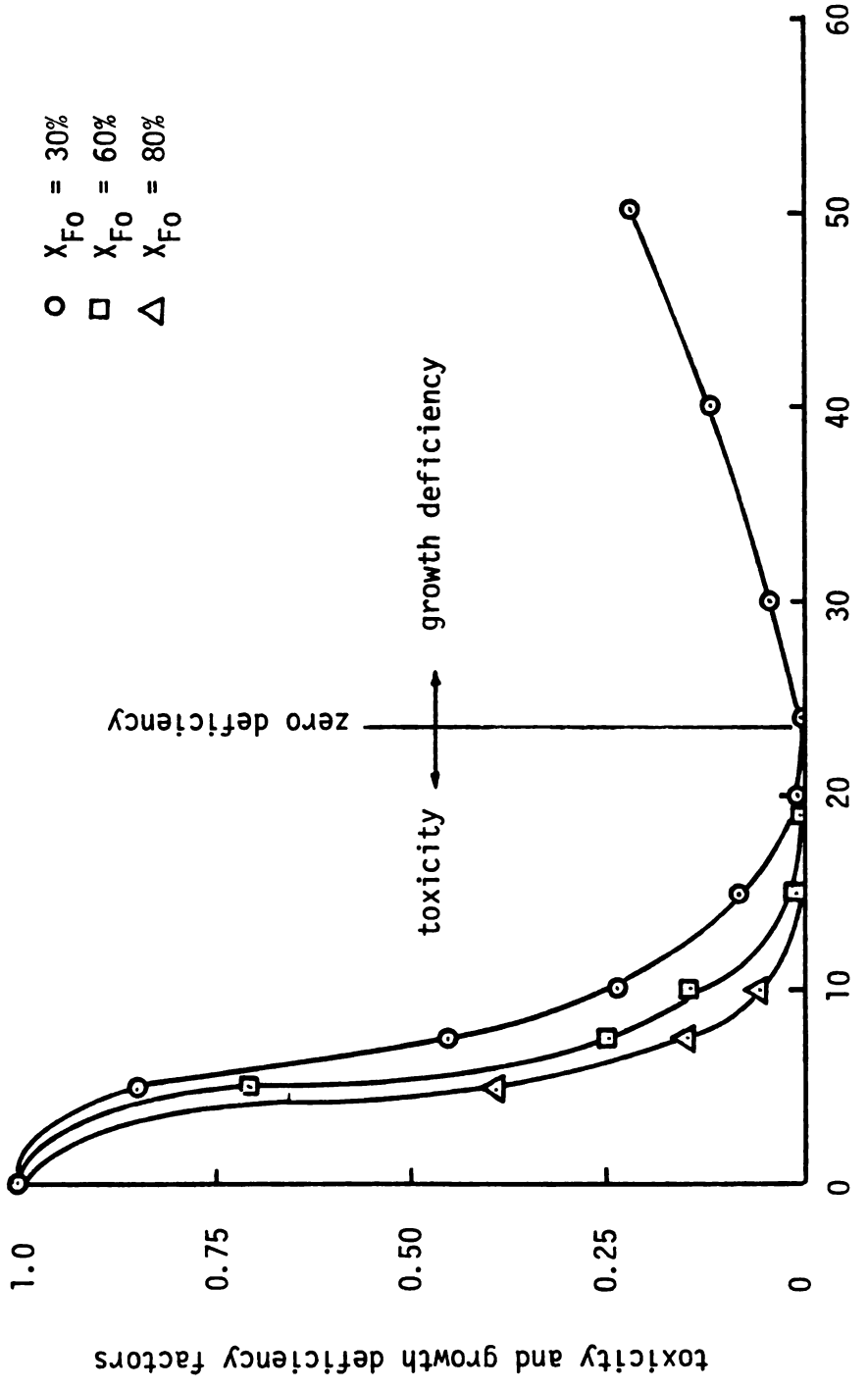


Figure 6.8.--Toxic and deficient growth factors versus carbon/nitrogen ratio, anaerobic conditions.

for maintenance over the large period of decomposition. The maximum experimental cell yield after 60 days of decomposition can be determined from Fig. 5.31 and is about (1 - 0.86) = 0.14. The calculated value can be determined using the relation

$$\bar{y} \cong \frac{y}{1 + k_d t} \qquad (6\text{-}1)$$

where $\bar{y}$ is the average cell yield, y is McCarty's cell yield (y = 0.54, section 2-B.5), k_d is a decay coefficient (k_d = 0.02 estimated for a batch system) and t is the detention time (60 days). This gives $\bar{y} = \frac{0.54}{1 + (0.02)(60)} = 0.2455$. A comparison of this value with the experimental value reveals an error of about 56%. This shows that McCarty's model overestimates the actual value by a considerable amount and that the model provides only an upper limit.

b. Anaerobic cell yield.--McCarty's model was used for prediction of cell yield under anaerobic conditions with a higher degree of success. The value predicted under ideal conditions of temperature, pressure, and pH (section 2.B.5) was found to be lower than that under aerobic conditions (y = 0.21, anaerobic). Two adjustments must be made to McCarty's calculated cell yield value. These include: (1) a correction must account for the concentration of reactants and products and (2) the possibility of low methane production must be considered, i.e., the main products are volatile acids. Using the procedure outlined in section 2.B.5 and assuming the following concentrations

$PCO_2 = 0.5$ atm

$PCH_4 = 0.5$ atm.

$[C_6H_{12}O_6] = 10^{-4.26M}$

This gives RT log e = 1.364

and δ = correction factor = $1.364 \log \left[\frac{(.5)^{1/8}(.5)^{1/8}}{(10^{-4.26})^{1/24}}\right] = 0.14.$

Recall that $\Delta G' = \Delta G^\circ + \delta = 5.763 + 0.14 = 5.90$

and $\Delta G_r^{\circ'} = -10.02 + 5.90 = -4.12$

Hence, $\Delta G'p = \Delta G^{\circ'}p + \delta p$ and the product reaction becomes

$$\frac{1}{24} C_6H_{12}O_6 + \frac{1}{10} HCO_3 = \frac{3}{20} H_2O + \frac{1}{20} CO_2 + \frac{1}{10} CH_3COCOO^-$$

$$\delta p = 1.364 \log \left[\frac{(PCO_2)^{1/20} (CH_3CPCOO)^{-1/10}}{(C_6H_{12}O_6)^{1/24}(HCO_3)^{1/10}}\right]$$

$$\delta p = 1.364 \log \left[\frac{(.5)^{1/20}(5 \times 10^{-5})^{1/10}}{(10^{-4.26})^{1/24}(10^{-1})^{1/10}}\right] = -0.23$$

$\Delta Gp = -1.475 - 0.23 = -1.71$

$$\Delta Gs = \frac{\Delta G'p}{K^n} + \Delta Gc = (0.6)(-1.71) + 7.5 = 6.48$$

$$A = -\frac{\Delta Gs}{K_1 \Delta Gr} = -\frac{6.48}{(.6)(-4.12)} = 2.62 = \frac{fe}{fs}$$

Recall that fe + fs = 1, fs + 2.62fs = 1, and fs = 0.2762.

Compute McCarty's cell yield as

$$y = \frac{(0.2762)(1/20)(113)}{(1/24)(180)} = 0.2081 \frac{\text{gm cells}}{\text{gm substrate}}$$

This cell yield compares very well with the value (.2100) given in section 2-B.5. The implication is that assumed concentrations have almost no influence on the calculated cell yield using standard conditions.

The maximum decomposition (X_{DI}) attained after 60 days under anaerobic conditions was 73%. Additional decomposition was possible due to the presence of fibers. If it is assumed that decomposition was complete, then the experimental cell yield should be $1 - X_{DI} = 1 - 0.73 = 0.27$. Using equation (6.1), the average cell yield, based on McCarty's model, becomes

$$\bar{y} = \frac{(0.2081)}{1 + (0.02)(60)} = 0.0945 \frac{\text{gm cells}}{\text{gm substrate}}$$

The predicted value (0.0945) is much less than the experimental value (0.27). This is exactly the opposite to the situation encountered under aerobic conditions. This suggests that additional decomposition was still possible under anaerobic conditions.

The assumption that the main products are volatile acids will result in a different cell yield. For this assumption and

using the procedure followed above, a new cell yield can be calculated.

Glucose ⇄ Acetate + Propionate + Methane, a reaction based on 1 mole of e^- transfer gives $\frac{1}{8}\ C_6H_{12}O_6 = \frac{1}{8}\ CH_3CH_2COO^- + \frac{1}{8}\ CH_3COO^- + \frac{1}{32}\ CH_4 + \frac{3}{32}\ CO_2 + \frac{1}{4}\ H^+ + \frac{1}{16}\ H_2O$ where [Ac] is 10^{-1}M = [Pr], PCO_2 is 0.75, PcH_4 is 0.25, $[C_6H_{12}O_6]$ is 10^{-4125M}, and pH is 6 = $[H^+] = 10^{-6}$. Therefore, $\Delta G°' = \Delta G°_f(P) - \Delta G°_f(R)$ and $\Delta G°_r{}' =$

$$\frac{1}{8}\ (-88.99) + \frac{1}{8}\ (-87.47) + \frac{1}{32}\ (-12.14) + \frac{3}{32}\ (-94.26) + \frac{1}{4}\ (-9.55) + \frac{1}{16}\ (-56.69) - (-219.22)\ \frac{1}{8} = -9.80$$

and $\Delta Gr' = \Delta G°_r{}' + \delta$

where $\delta = 1.364 \log \left[\frac{(0.75)^{3/32}(0.25)^{1/32}(10^{-1})^{1/8}(10^{-1})^{1/8}}{(10^{-4.25})^{1/8}}\right] = 3.04$

This gives $\Delta Gr' = -0.8 + 0.34 = -.46$

Adding products and reactants gives:

$$\frac{1}{24}\ C_6H_{12}OG + \frac{1}{10}\ HCO_3^- = \frac{1}{10}\ CH_3COCOO^- + \frac{3}{20}\ H_2O + \frac{1}{20}\ CO_2$$

The concentration of bicarbonate is calculated as follows:

$$CO_2(g) + H_2O = H_2CO_3 \quad (KH = 10^{-1.59})$$

$$H_2CO_3 \rightleftarrows H^+ + HCO_3^- \quad (KH = 10^{-6.3})$$

$$[H_2CO_3] = 10^{-1.59} \times 0.75 \text{ atm} = 1.93 \times 10^{-2} = k$$

$$[HCO_3^-] = \frac{K\,[H_2CO_3]}{[H^+]} = \frac{10^{-6.3} \times 1.93 \times 10^{-2}}{10^{-6}} = 10^{-2}$$

$$\delta p = 1.364 \log \left[\frac{(CH_3COCOO^-)^{1/10}\,(PCO_2)^{1/20}}{(C_6H_{12}O_6)^{1/24}(HCO_3^-)^{1/10}}\right] = -0.08$$

$$\Delta G_p' = \Delta G_p^{\circ\prime} + \delta p$$

where $\Delta G_p^{\circ\prime} = 1.475$ as given in section 2-B.5.

$$\Delta G_p' = -1.475 - 0.08 = -1.56$$

$$\Delta G_S = \frac{\Delta Gp}{k^n} + \Delta Gc = (0.6)(-1.56) + 7.5 = 6.57$$

$$A = \frac{f_e}{f_s} = -\frac{\Delta Gs}{K_1 \Delta Gr} = \frac{-6.57}{-9.46} = 0.69$$

Recall that $f_s + f_e = 1$, hence, $f_s + 0.69\ f_s = 1$ and $f_c = 0.59$. Therefore, the predicted cell yield

$$y = \frac{(0.59)(1/20)(113)}{1/8\ (180)} = 0.15\ \frac{\text{gm cells}}{\text{gm substrate}}$$

If cell decay is taken into account, the calculated average cell yield (equation 6-1)

$$\bar{y} = \frac{(0.15)(100)}{1 + (0.02)(60)} = 0.068\ \frac{\text{gm cells}}{\text{gm substrate}}.$$

Again, the predicted cell yield is lower than the experimental value (0.27). A final conclusion can be drawn to the effect that anaerobic systems have a predicted cell yield value lower than aerobic systems, which have a higher predicted value than the experimental.

4. Organic Content Determination (Reliability)

One of the objectives of this research project was to develop a method by which the organic content of a given soil mass could be determined accurately with minimum effort. The initial problem involved the type of mineral and organic matter encountered in organic soils. Fortunately, the predominant elements encountered in organic soils include mainly clay, sand, silt, and cellulose. The second problem involved determination of the thermal characteristics for these materials. This problem was much more involved because of the different clay types and the amount of adsorbed water they contain. Weight loss versus duration for several temperatures are given in Figs. 5.1, 5.3, and 5.4 for cellulose, kaolinite, and montmorillonite, initially air dried at room temperature (25°C). Sand samples initially dried at 100°C were found to be very stable at higher temperatures (weight loss of approximately 1% was observed at a temperature of 900°C). This 1% weight loss for sand was considered small enough to be tolerated in subsequent calculations. The weight loss experienced by different clay groups, due to dehydration, could reach 14% (Fig. 5.5) provided samples were initially dried to 105°C. An examination of temperature curves for numerous clays showed that weight losses could be bounded if samples were first dried at 100°C. Montmorillonite provided a lower bound and kaolinite an upper bound. As a result more accurate temperature curves were obtained for kalinite and montmorillonite showing weight loss versus temperature and duration (Figs. 5.3 and 5.4). The

usefulness of these figures were demonstrated in the derivation of the two component and the n-component ash analysis systems, and finally the general approach presented in section 5-A.

The reliability of the ash analysis in organic content determinations depends on information available for the mineral types in a given soil sample. The errors associated with conventional ash methods for organic content determination come about because these methods do not take into account weight losses due to mineral dehydration. A general classification of the possible problem types which the ash technique may encounter includes two cases: (1) mineral types known, and (2) mineral types unknown.

a. Known mineral types.--For an organic soil sample with known mineral types, the n-component system (5-A.2) can be used. Fortunately, there is no restriction on the choice of temperature or duration in conducting this test. It is desirable to choose a high temperature if the equipment is adequate. The advantage is that a low duration for burning can be accomplished, consequently, this test is fast, simple, and accurate to about ± 1%.

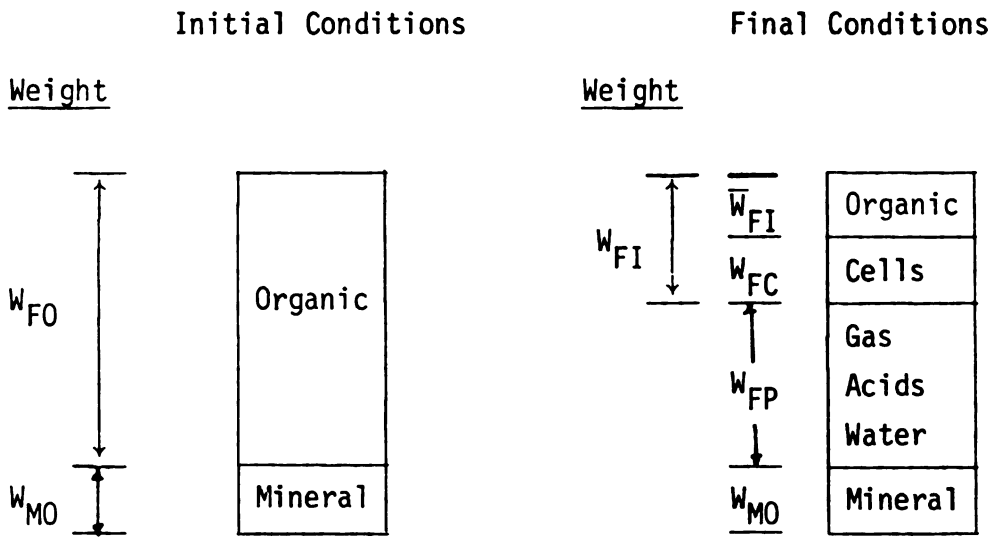
b. Unknown mineral types.--This problem will probably be encountered in most cases. It requires a careful and systematic approach for its solution. Consider first a slow test. Regardless of mineral type, the maximum weight loss of kaolinite, montmorillonite, and sand is about 2% at a temperature T = 400°C and duration D = 12 hours (Fig. 5.14). For this temperature and duration, complete combusion of the organic fiber is possible. Equations 5-2

and 5-3 were used to determine the organic and mineral content. The method is reliable and does not err by more than about 1%. The drawback is the test duration of 12 hrs. A fast test, using a high temperature requires the minimum time of combustion. For a mineral combination of kaolinite, montmorillonite, and sand, selection of a 900°C temperature and 1.25 hrs. duration gives the following weight losses due to dehydration: kaolinite (14%), montmorillonite (6%), and sand (1%). These values require that soil samples be initially dried at 105°C. If the mineral is predominantly clay, an average value of weight loss may be taken as $\frac{14 + 6}{2}$ = 10%. Using Equation 5-1, the maximum possible error would be about 4%. On the other hand, if the mineral is predominantly sand, an average weight loss value of $\frac{10 + 1}{2}$ = 5.5% should be used with a maximum possible error of about 4.5%. For the case where the predominent mineral is unknown, use an average value of $\frac{14 + 6 + 1}{3}$ = 7% for weight loss. In general, equation 5-1 can be used with a maximum possible error of about 7% for a fast test. This will occur only if the mineral is 100% kaolinite. This is usually not the case for natural organic soils. Note that the maximum 7% error is less than half the error encountered using conventional ash content methods and the 900°C temperature for organic content determination. The possible loss in accuracy using the fast test method may in some cases compensate for the fewer hours spent on testing.

5. Decomposition Measurement

The technique presented in section 4-B was made possible by assuming that the organic content consists of both decomposed matter (microbial cells) and undecomposed organic matter. The percent decomposition based on equation 4-15 would always underestimate the actual value. This condition occurs because there is no way to separate the weight of microbial cells from that of the undecomposed organic matter. Hence, there was a need to make corrections that would lead to a more concise equation and thereby eliminate the error. One way of approaching this problem was to compute the microbial cell content of a given soil, then subtract that value from the total organic content. Next compute the actual percent decomposition using equation 5-1. This approach is difficult for a geotechnical engineer with limited information on the soil. The other alternative is to lump the microbial cell content and undecomposed organic content together, then introduce a correction cell yield factor. This is possible with no loss of accuracy. For the initial conditions, it is known that a given soil sample will contain organic matter and minerals. After a given degree of decomposition some of the organic matter may remain and part will be transformed and used in the production of new microbial cells, gases, volatile acids, and water. The mineral part will undergo no transformation, except for the dehydration described earlier.

Two phase diagrams representing initial (before decomposition and dried to 105°C) and final conditions (after decomposition) are shown as follows:



The cell yield Y in a given biomass was defined in Chapter II and can be expressed as a function of W_{FC}, W_{FO}, and $\overline{W}_{FI}$ as:

$$Y = \frac{W_{FC}}{W_{FO} - \overline{W}_{FI}} = \frac{W_{FC}}{W_{FC} + W_{FP}} \qquad (6\text{-}2)$$

Decomposition (percent) was defined in Chapter IV and can be expressed as:

$$X_{DI} = \frac{W_{FC} + W_{FP}}{W_{FO}} \quad \text{or}$$

$$W_{FC} + W_{FP} = X_{DI} W_{FO} \qquad (6\text{-}3)$$

Substituting Equation 6-3 into Equation 6-2 gives the cell yield

$$Y = \frac{W_{FC}}{X_{DI} W_{FO}}$$

Rearrange as

$$W_{FC} = Y\ X_{DI} W_{FO} \tag{6-4}$$

$$X_{DI} = \frac{W_{FO} - \overline{W}_{FI}}{W_{FO}} \tag{6-5}$$

$$X_{DI} = \frac{W_{FO} - W_{FI} + W_{FC}}{W_{FO}}$$

$$X_{DI} = \frac{W_{FO} - W_{FI}}{W_{FO}} + \frac{W_{FC}}{W_{FO}} \tag{6-6}$$

But from equation (6-4) $\frac{W_{FC}}{W_{FO}} = Y\ X_{DI}$. Substitution into equation (6-6) gives:

$$X_{DI} = \frac{W_{FO} - W_{FI}}{W_{FO}} + Y\ X_{DI}$$

or $$X_{DI} - Y\ X_{DI} = \frac{W_{FO} - W_{FI}}{W_{FO}} \tag{6-7}$$

Examination of the right hand side of equation (6-7) reveals that the same equation was used in the derivation of the original decomposition (equation 4-9). Equation (6-7) can be rewritten as:

$$X_{DI}\ (1 - Y) = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$$

or $$X_{DI} = \left(\frac{1}{1 - Y}\right)\left[\frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}\right] \tag{6-8}$$

Equation (6-8) gives the percent decomposition (X_{DI}) as a function of the cell yield (y), the initial organic content (X_{FO}), and present organic content (X_{FI}). It is independent of the decomposition process, whether aerobic or anaerobic. Note that the organic content after decomposition is the total value of both cells and undecomposed organic matter. The cell yield coefficient (Y) depends on many factors (see section 6-B.3) and further research is needed for a more accurate determination. At this time Y = 0.10 may be used for the anaerobic decomposition process and Y = 0.20 may be used for the aerobic case.

C. Consolidation Parameters

This section considers the compressibility of organic soil, the parameters affecting compressibility, and how they in turn are affected by decomposition.

1. Void Ratio

The void ratio of a given soil describes to a certain extent its compressibility, the higher the initial void ratio, the greater the potential compressibility. Unlike mineral soils, the void ratio of organic soils is usually very high (section 2-C). Unfortunately, little is known of decomposition effects and that of incremental stress on void ratio. One of the primary objectives of this research project was to provide additional information on this question. The void ratio for three different organic contents have been plotted for samples with different C/N ratios and different

stress increments in Fig. 5.21. The experimental data show an approximate linear relationship between void ratio and organic content. The stress increment has a considerable effect on the void ratio for a given organic content. This has been shown to be the case by many researchers (MacFarlane, 1969). The void ratio for decomposed materials was plotted as a percent of the initial void ratio (undecomposed) vs. percent decomposition in Fig. 5.45. The three curves in this figure represent organic contents of 30, 60, and 80%. These curves show, irrespective of the organic content, that the stress increment has very little or no influence on the ratio of final/initial void ratio. The implication is that the relationship between void ratio and stress increment is independent of the amount of decomposition. An initial increase followed by a decrease in the ratio of final/initial void ratio is also exhibited in Fig. 6.9. This increase is higher for the higher organic contents. The ratio of final/initial void ratio vs. percent decomposition is plotted for 30% organic content under aerobic decomposition conditions in Fig. 6.9. Curves for the 60% and 80% initial organic contents are not shown due to insufficient material remaining after decomposition. However, for the 30% organic content this figure does show a different behavior from that under anaerobic conditions. A substantial decrease in the ratio of final/initial void ratio occurred as decomposition progressed under aerobic conditions. The major difference between aerobic and anaerobic decomposition is the amount water required for sufficient aeration in the aerobic case and saturation

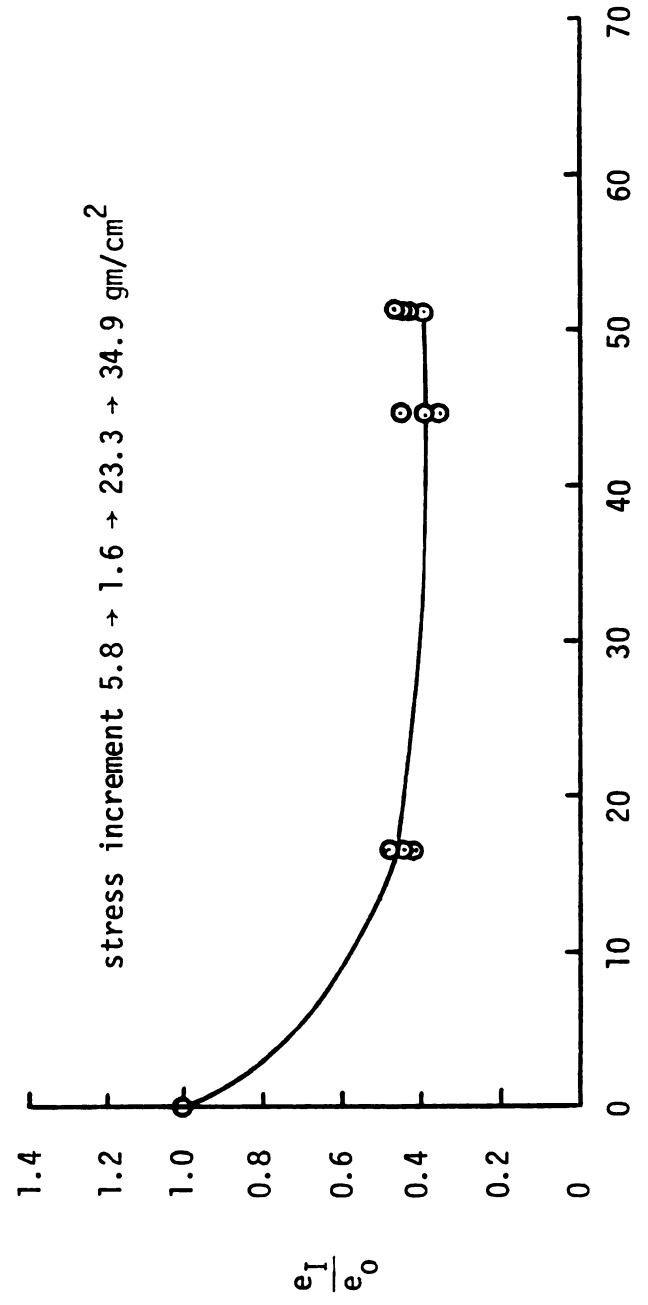


Figure 6.9.--Void ratio, ratio of decomposed to initial value, versus percent decomposition, 30% initial organic content, aerobic conditions.

in the anaerobic case. The difference in behavior of Fig. 6.9 and 5.45 may be explained on that basis. Gases produced under the anaerobic condition are prevented from leaving the voids by adjacent water molecules occupying the void space. They are in effect trapped while gases liberated in the aerobic case will be able to escape these voids. The consequence is a higher void ratio for higher gas contents. This difference in behavior could be critical in that it introduces a new parameter, that is, the dependency of some engineering properties not only on decomposition, but also on the type of decomposition. The one similarity between Figs. 6.9 and 5.45 is that once again the relationship between the void ratio and stress increment is independent of the amount of decomposition.

2. Coefficient of Permeability

The coefficient of permeability k for a given soil determines its time rate of consolidation. This parameter can be influenced by many factors, some of which were discussed in section (2-A.4). Decomposition appears to have a large influence on the magnitude of k for organic soils (Fig. 5.49). The decrease in the coefficient of permeability may be attributed to the decrease in length, diameter, and surface characteristics of the fiber which constitute the organic fraction in these samples. The stress increment appears to have little influence. However, this could be due to experimental errors. The decrease in permeability with increasing decomposition appears to occur irrespective of the initial organic content. For the

discussion to be complete, the effects of initial C/N ratio was also included in Fig. 6-10. The coefficient of permeability appears to increase initially for a low degree of decomposition and they decrease for higher degrees of decomposition. The initial increase may be attributed to the utilization of nutrients by micro-organisms, hence a decrease in viscosity of the pore fluid. The decrease in permeability at higher degrees of decomposition may be explained by the transformation of large particles (cellulose fibers) to smaller ones strictly by microbial action. These smaller particles, all surrounded by adsorbed water molecules, effectively take up more volume and thereby reduce pore space available for flow. The coefficient of permeability is high for larger particles. Note that the highest increase in the coefficient of permeability occurred for the highest nutrient concentrations (C/N = 5:1) as a result of decomposition. The coefficient of permeability was found to be higher for high organic contents and no decomposition (Fig. 5.24). The stress level increment has a significant effect on permeability as shown in these figures. The coefficient of permeability, plotted against the C/N ratio in Fig. 5-24 shows that the permeability increases with increasing C/N ratio when no decomposition has taken place.

3. Compression Index C_c

Soil consolidation parameters are influenced by the changes which soils undergo during decomposition. Organic content and

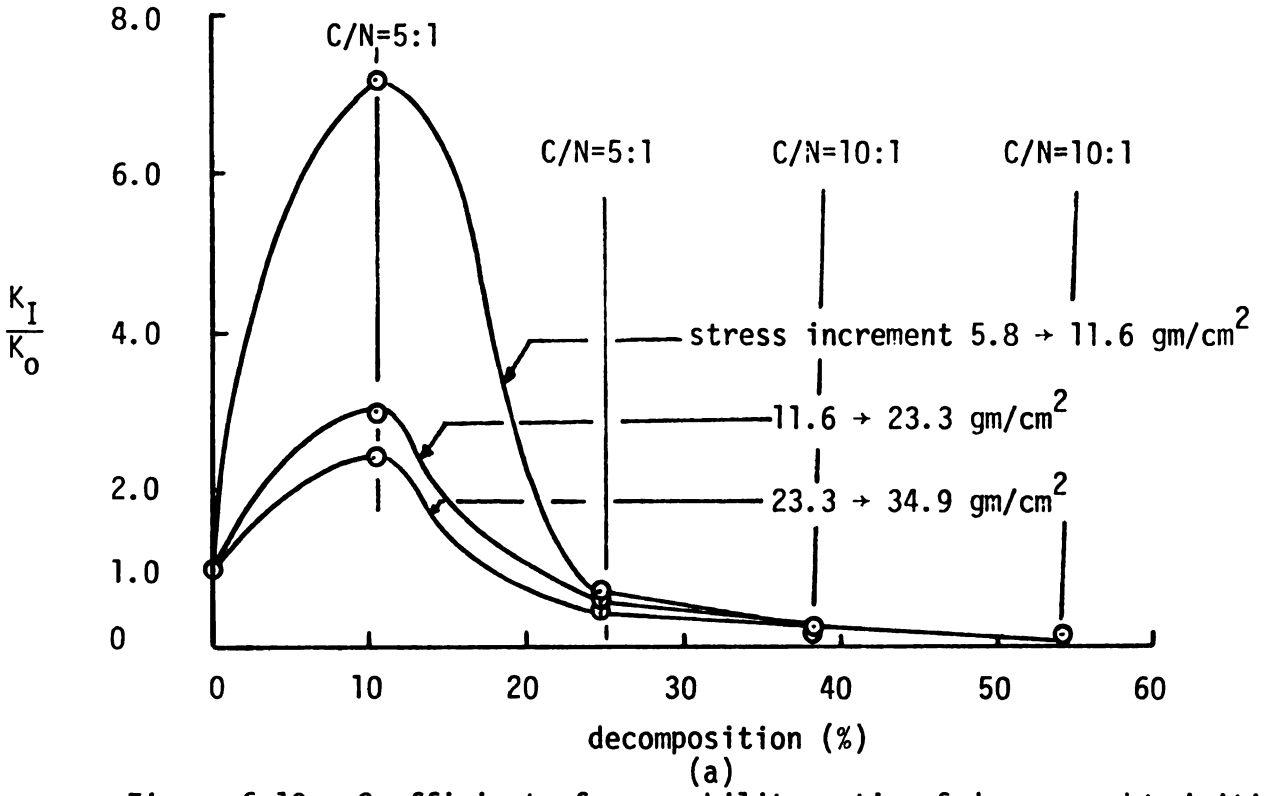
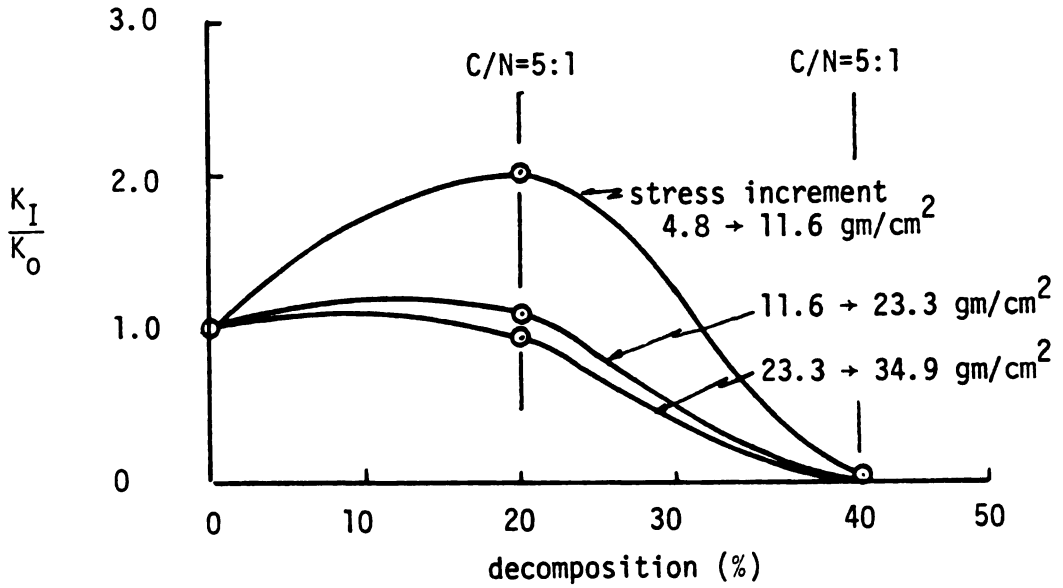
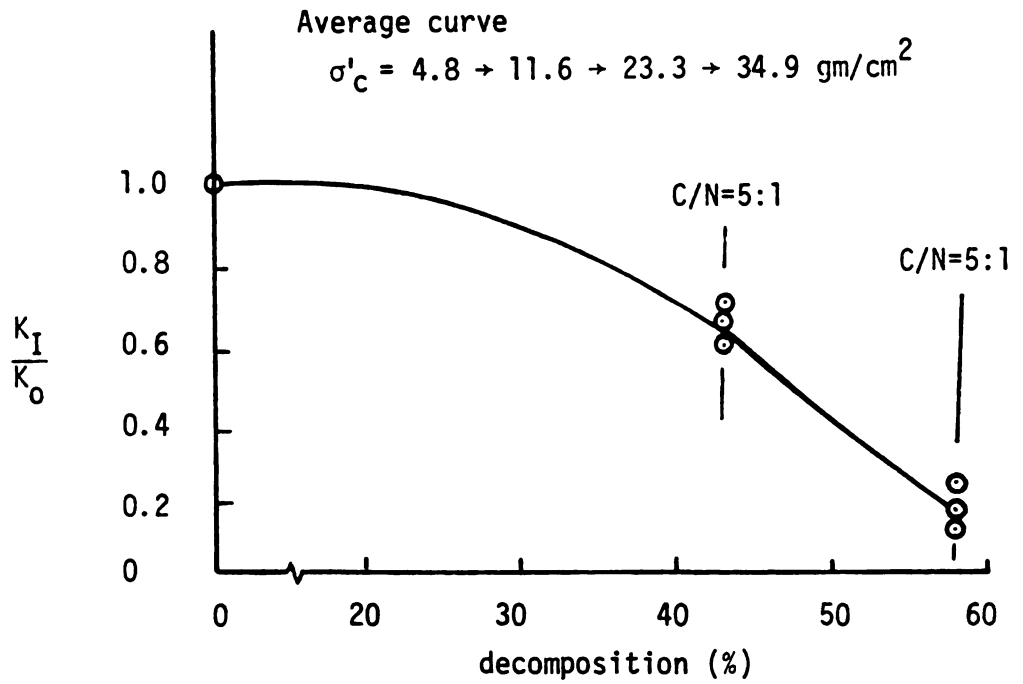


Figure 6.10.--Coefficient of permeability, ratio of decomposed to initial value versus percent decomposition, variable carbon/nitrogen ratio, anaerobic conditions. (a) 30% initial organic content. (b) 60% X_{Fo}. (c) 80% X_{Fo}.



(b)



(c)

Figure 6.10.--Continued

stress level are seen to have the greatest influence on the compression index. The conventional consolidation theory for mineral soils cannot account for these changes. Different expressions have been proposed relating the compression index to some physical properties; however, not all factors are adequately accounted for. Equations given by Cook (1956), Miyakawa (1960), and Moore (1962), suggest that the compression index is dependent on the water content in a given organic soil, for example, C_c = 0.007 w and C_c = 0.011 w were reported. Although these equations may have some application to specific soils, their usefulness is very limited. A highly organic soil with a low natural water content can erroneously give a compression index close to zero. Consequently, a restriction is placed on the use of these equations. This restriction may be that the moisture content is that of saturation, however this is not stated. Lea and Brawner (1963) gave the compression index as a function of void ratio where C_c = (0.45 to 0.75) e. Again, it is noted that the void ratio is also a function of the stress level. Recognizing the difficulties encountered in relating C_c to physical parameters, the need for an independent parameter was apparent. Organic content of a given soil appeared to be independent of stress-increment, hence it was selected as an independent variable. Data reported by Khattak (1978) suggested that stress level was also an independent parameter. The range of C_c determined experimently in this research program corresponds very well with published data reported by Kogure (1977). Consequently, both organic content and stress level were used as

independent variables, in the derivation of a functional relationship. This was accomplished using data reported by Khattak (1978) and data from this project (Figs.2.8 and 5.19). Three equations relating void ratio to stress level for organic contents of 100%, 40%, and 16% were derived.

$$e_{100} = 3.39\ [\log p]^2 - 12.01\ [\log p] + 11.6 \qquad (6\text{-}8)$$

$$e_{40} = 1.46\ [\log p]^2 - 5.39\ [\log p] + 5.63 \qquad (6\text{-}9)$$

$$e_{16} = 0.88\ [\log p]^2 - 3.30\ [\log p] + 3.77 \qquad (6\text{-}10)$$

Using the definition for the compression index and Equations 6-8, 6-9, and 6-10 gave the following expressions:

$$C_{c100} = -2.95 \log p + 5.22 = -\frac{\Delta e_{100}}{\Delta \log p} \qquad (6\text{-}11)$$

$$C_{c40} = -1.27 \log p + 2.34 = -\frac{\Delta e_{40}}{\Delta \log p} \qquad (6\text{-}12)$$

$$C_{c16} = -0.77 \log p + 1.64 = -\frac{\Delta e_{16}}{\Delta \log p} \qquad (6\text{-}13)$$

Examination of these equations revealed the following equations:

$$\frac{C_{c100}}{-2.95 \log p + 5.22} = 1.00 \qquad (6\text{-}14)$$

$$\frac{C_{c40}}{C_{c100}} = 0.43 = \frac{C_{c40}}{-2.95 \log p + 5.22} \qquad (6\text{-}15)$$

$$\frac{C_{c16}}{C_{c100}} = 0.26 = \frac{C_{c16}}{-2.95 \log p + 5.22} \qquad (6.16)$$

Equations 6-14, 6-15, and 6-16 are plotted against their respective organic contents in Fig. 6.11. The figure shows that a linear relationship exists between the compression index ratio and organic content, thus

$$\frac{C_c}{-2.95 \log p + 5.22} = 0.9\ X_{FO} + 0.10 \qquad (6\text{-}17)$$

or $$C_c = -2.66\ X_{FO} \log p + 4.70\ X_{FO} - 0.295 \log p + 0.522$$

$$C_c = -(2.66\ X_{FO} + 0.30) \text{ Log } p + 4.70\ X_{FO} + 0.522$$

$$C_c = (0.52 + 4.70\ X_{FO})(1 - 0.56 \log p)$$

$$C_c = (0.52 + 4.70\ X_{FO})(\log 10 - 0.56 \log p)$$

$$C_c = (0.52 + 4.70\ X_{FO}) \log (10/p^{0.56})$$

The restriction is $.001 < p < 50$ kg.

$$C_c = (0.52 + 4.70\ X_{FO})\ \varepsilon \qquad (6\text{-}18)$$

where $\varepsilon = \log (\frac{10}{p^{0.56}})$ is a factor dependent on stress level. A plot of ε vs. p is shown in Fig. (6.12). The compression index for an organic soil can be predicted using Equation 6-18, if the organic content and the stress level are known. In Chapter II an organic

soil was defined on a qualitative rather than quantitive basis. A quantitive definition may now be possible using the following facts:

1. The compression index for an inorganic soil is generally independent of the stress level
2. The maximum compression index for most natural inorganic clays is usually less than 1.0 (Grim, 1968; Mitchell, 1976)

A constant compression index for an inorganic soil means that the compression index stress factor ε is equal to 1.0. This implies that the stress level P = 1.0. Substituting ε = 1.0 and C_c = 1.0 into Equation 6-18 and solving for X_{FO} gives

$$1 = (0.52 + 4.70\ X_{FO})(1)$$

$$X_{FO} \geq +10\%$$

This definition states that a soil should be labeled organic when the organic content is 10% or greater. This value represents the minimum organic content needed for a significant change in the compressibility of a given soil compared to that of an inorganic soil.

Having discussed the influence of stress level and organic content on the compression index for initial conditions (no decomposition), it is appropriate to study the influence of decomposition and the effect of gases liberated during the decomposition process on C_c The compression index C_c was plotted against percent decomposition in Fig. 5.47. A second plot shows the decomposed/undecomposed ratio of C_c vs. percent decomposition in Fig. 5.48. The general behavior shows an increase in C_c due to decomposition

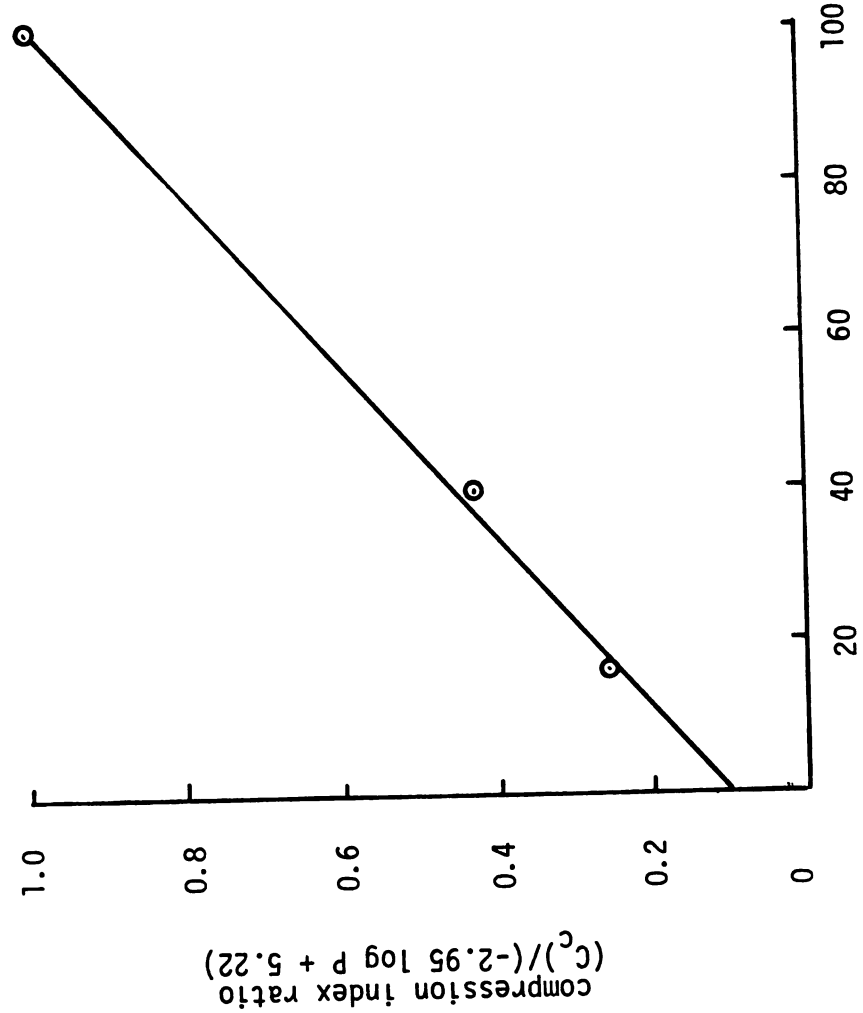


Figure 6.11.--Compression index ratio versus initial organic content.

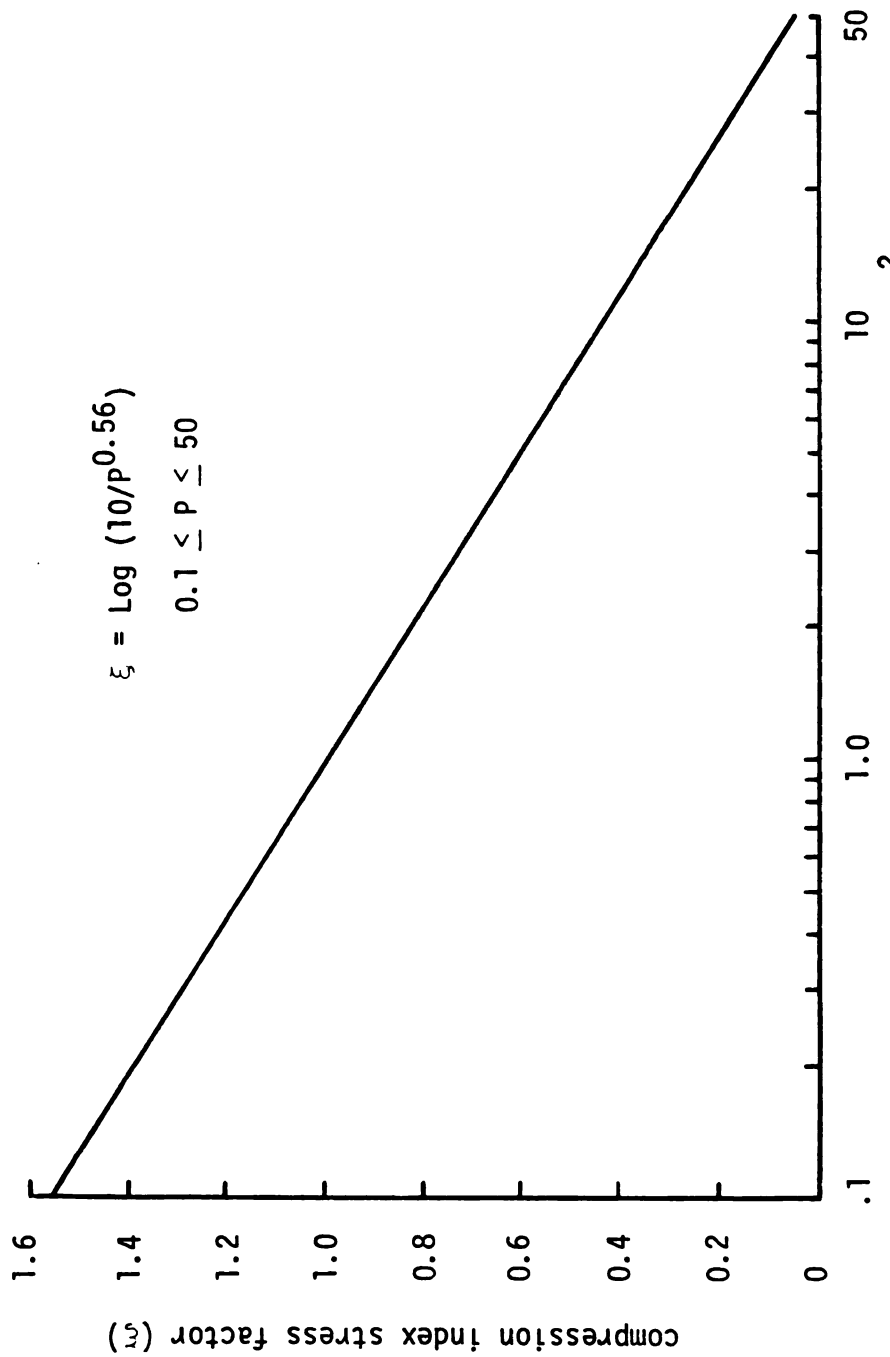


Figure 6.12.--Compression index stress factor versus normal effective stress level.

followed by a subsequent decrease for higher degrees of decomposition. The absolute value of C_c is seen to be dependent on the organic contents before and after decomposition. The increase in compressibility after initial decomposition may be attributed to gas production brought about by micro-organisms decomposing part of the organic fiber. This effect results in a higher void ratio, hence increasing compressibility as discussed in section 6-C.1. The subsequent decrease in C_c may be explained by the destruction of fiber structure as described in section 6-A.1. The decomposition process reduces fiber size and contributes to a collapse of the fibrous soil into clay particles and a fine decomposed by-product. The decrease in C_c would be expected to approach that of the clay corresponding to 100% decomposition. It is apparent that a reduction in organic matter due to decomposition cannot be fully simulated by simply removing corresponding amounts of organic matter. The values of C_{cI}/C_{co} in Fig. 6.13 for $X_{FI} < 30\%$ represent samples containing gas and a degree of saturation less than 100%. Examination of these curves show that the general behavior of the compression index ratio (C_{cI}/C_{cO}) versus decomposition (X_{DI}) is independent of the organic content and can be represented by one curve. This suggests that gases produced during the decomposition process have about the same effect on C_c irrespective of the organic content. An average curve, representing C_{cI}/C_{co} versus X_{DI}, is given in Fig. 6.13.

4. Coefficient of Consolidation

The consolidation rate in organic and inorganic soils is reflected by the coefficient of consolidation, c_v. The larger the c_v value, the greater the rate of consolidation. Like a_v and k, c_v is influenced by the soil type, organic content, degree of saturation viscosity of the pore fluid, and degree of decomposition. The conventional consolidation theory does not allow for the presence of gases in the consolidating medium for which c_v is to be calculated. Experimental data plotted for aerobic samples in Fig. 5.43 through 5.46 show c_v versus initial organic content (X_{FO}) for various carbon to nitrogen ratios (C/N) and consolidation pressures. No logical trend for c_v is apparent except that it increases with increasing organic content for C/N = 5:1 (S_r = 100%) and it decreases with increasing organic content for C/N = 10, 30, 50 (S_r < 100% being lower for high C/N). The presence of gas bubbles (S_r < 100%) would reduce k and thereby decrease c_v. The coefficient of consolidation is plotted vs. X_{FO} for samples tested under anaerobic conditions (S_r = 100%) in Fig. 5.15. The general trend seems to be a definite increase in c_v with increasing X_{FO}, irrespective of C/N or the consolidation pressure. This behavior may be explained on the basis that a higher organic content will result in a higher void ratio, a higher permeability and therefore an increase in c_v.

The decomposition effect on c_v is shown in Fig. 5.39, with curves representing different C/N. The separate effects of C/N and decomposition are shown in Fig. 5.46. With decomposition c_v decreases

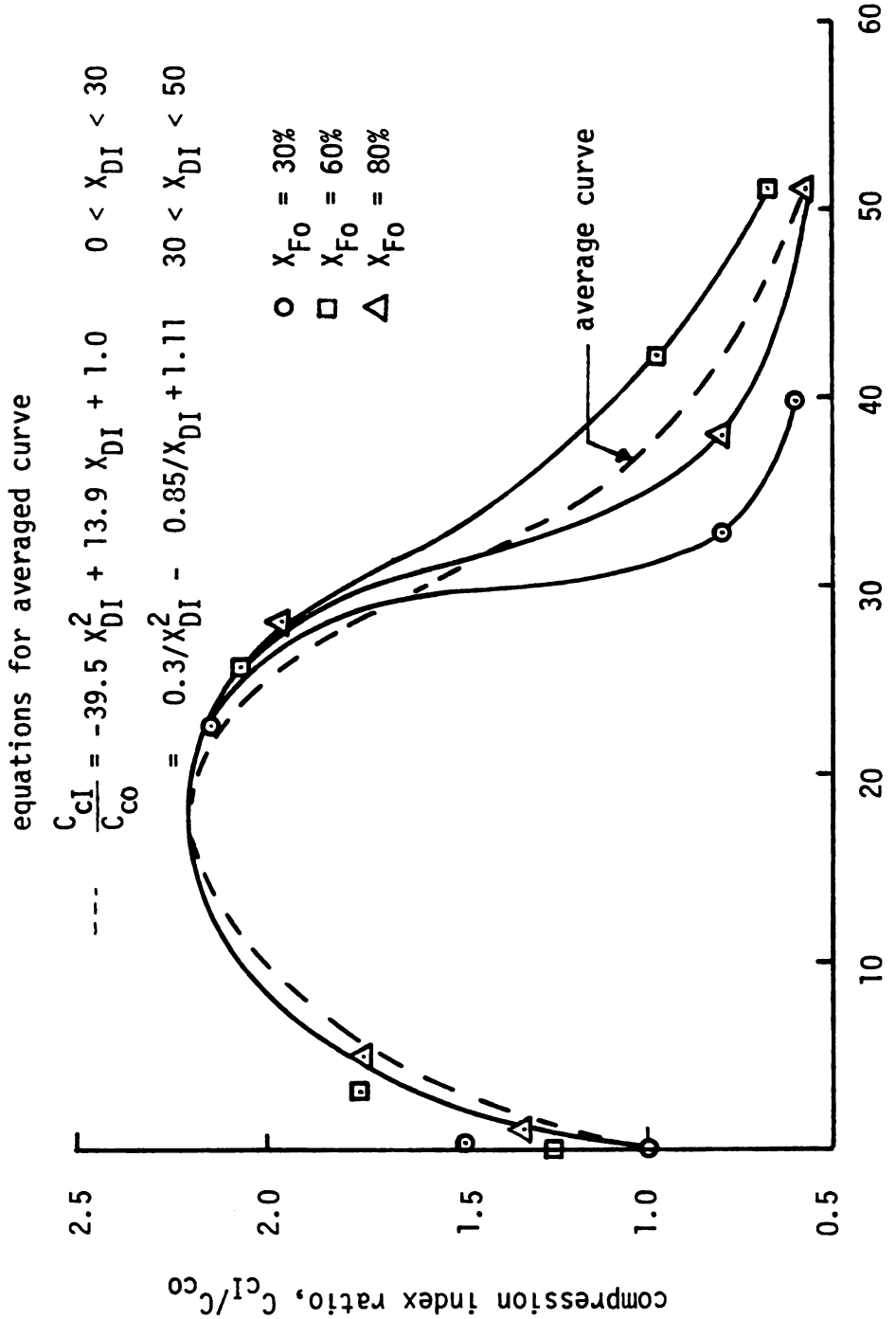


Figure 6.13.--Compression index ratio of decomposed to initial value versus percent decomposition showing the gas effect for a 30:1 carbon/nitrogen ratio and anaerobic conditions.

for C/N = 30:1 and for all consolidation pressures. This decrease in the rate of consolidation may be caused by degradation of the fibers into smaller particles with a reduction in permeability and void ratio. Considering the following equation:

$$c_v = \frac{k\ (1 + e)}{a_v\ \gamma w}$$

It is obvious that both k and e would tend to reduce the rate of consolidation as a result of decomposition.

5. Decomposed to Initial Soil Height Ratio

The decomposed to initial soil height ratio (H_D/H_o) relates the reduced sample height due to decomposition to the initial sample height. Often times when dealing with ultimate settlement, the reduction in height due to decomposition is ignored. For organic soils this portion of the settlement can be more significant than the consolidation settlement term. A plot of the (H_D/H_o) ratio versus decomposition is shown in Fig. 5.37 for the aerobic case and Fig. 5.44 for the anaerobic case. The reduction in height is attributed in part to the loss of solids due to microbial activity. The relationship between (H_D/H_o) and X_{DI} can be expressed mathematically as

$$(H_D/H_o) = 1 - 1.82\ X_{DI}^{1.52} \qquad (6\text{-}19)$$

This equation is valid between X_{DI} = 0 and X_{DI} = 50%. Fig. 5.44 also shows the relationship between the ratio H_D/H_o and X_{DI} but it

includes in addition the effects of different C/N ratios. The stress increment of 23.3 → 34.9 gm/cm^2 was selected so as to minimize the effects of entrapped gas bubbles.

6. Ultimate Settlement

The ultimate settlement of a consolidating mineral soil layer can be determined using conventional methods. Unfortunately, these methods cannot be applied to organic soils for the following reasons:

1. The equation for ultimate settlement

$$\Delta H = \frac{H_o C_c}{1 + e_o} \log \frac{P_o + \Delta P}{P_o}$$

does not take into account the effect of decomposition on C_c (or Δe) and H_o.

2. The equation assumes a linear relationship between e and log p which is typical for inorganic soils. This relationship is nonlinear for organic soils (Fig. 2.8), hence this fact must be accounted for when applied to organic soils. The simple linear e-log p relationship cannot be used and the dependence of sample height (or void ratio) on both organic content and stress level must be taken into consideration.

a. Ultimate settlement with no decomposition.--The ultimate settlement of organic soils (ΔH) can be expressed in terms of consolidation settlement (ΔH_c), secondary compression (ΔH_α), and settlement due to solids decomposition (ΔH_D), thus:

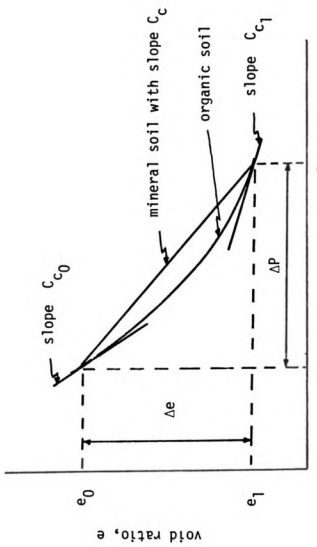


Figure 6.14.--Schematic diagram of void ratio versus normal effective stress for mineral and organic soils.

$$\Delta H = \Delta H_c + \Delta H_\alpha + \Delta H_D \qquad (6\text{-}20)$$

for no decomposition ($\Delta H_D = 0$), equation (6-20) becomes:

$$\Delta H = \Delta H_c + \Delta H_\alpha \qquad (6\text{-}21)$$

The parameters used in ultimate settlement calculations are relatively constant for small stress increments. Higher stress increments show the influence of organic content (X_{FO}) on the soil compressibility characteristics. The experimental data indicated that stress level and organic content of a given soil deposit were the main parameters needed for calculation of ultimate settlement in organic soils. Examination of Fig. 5.14 shows that Δe for mineral soils can be conveniently determined as $C_C \log \frac{P_2}{P_1}$. For organic this is not the case because C_c is also dependent on the stress level. The difficulty in determining Δe can be overcome by calculating the void ratio at the selected stress levels, then $\Delta e = e_o - e_1$. The ultimate settlement due to primary consolidation can now be expressed as:

$$\Delta H_c = \frac{H_o \, \Delta e}{1 + e_o} = \frac{H_o \, (e_o - e_1)}{1 + e_o} \qquad (6\text{-}22a)$$

where e_o is dependent on the initial overburden stress P_o and the initial organic content X_{FO}, and e_1 is dependent on the initial organic content and the stress increment plus the initial overburden stress ($P_1 = P_o + \Delta P$), therefore:

$$\Delta H_c = H_o \frac{e_o(P_o, X_{FO}) - e_1 (P_1, X_{FO})}{1 + e_o (P_o, X_{FO})} \qquad (6.22.b)$$

A functional relationship between e and P for a given X_{FO} was obtained using data from this project and data summarized in Fig. 2.8. The linear relationships observed between e and X_{FO} for selected stress levels (0.05, 2.4, 7, 10, 30, and 100 kg/cm^2) in Fig. 6.15 permitted the derivation of six basic linear functions which relate e to X_{FO}. Both the intercepts (C) and the slopes (m) from these equations depend on the stress level only. This dependence on stress made possible a general linear equation relating e to X_{FO} thus:

$$e(P, X_{FO}) = C (P) + m (P) X_{FO} \qquad (6\text{-}24)$$

where C (P) is an intercept function dependent on P, and m (P) is a slope function dependent on P. This equation (6-24) permits the uncoupling of the stress level and organic content effects on the void ratio. Using the intercepts and slopes from the six equations derived in Fig. 6.15 C (P) and m (P) are plotted against stress level (P) in Fig. 6.16. It is now possible to determine the void ratio for any stress level (0.05 to 100 kg/cm^2) and organic content (0 to 100%) using equation 6-24 and Fig. 6.16.

The settlement due to secondary compression depends on the coefficient of secondary compression C_α and time as shown in Equation 6-25 (MacFarlane, 1969).

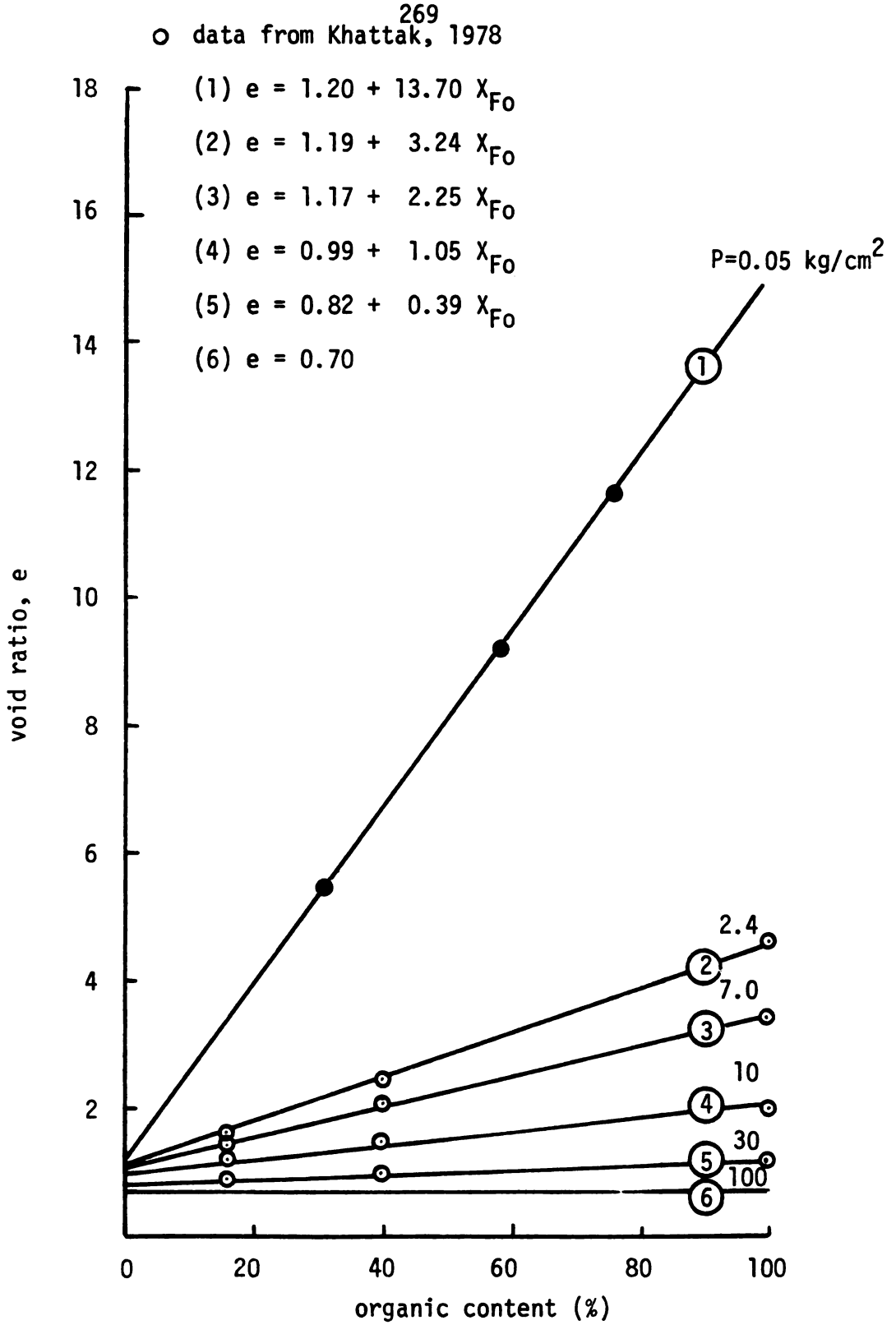


Figure 6.15.--Interrelationships between organic content (X_{Fo}), void ratio (e), and consolidation pressure (P) for fiber/Kaolinite soil mixtures.

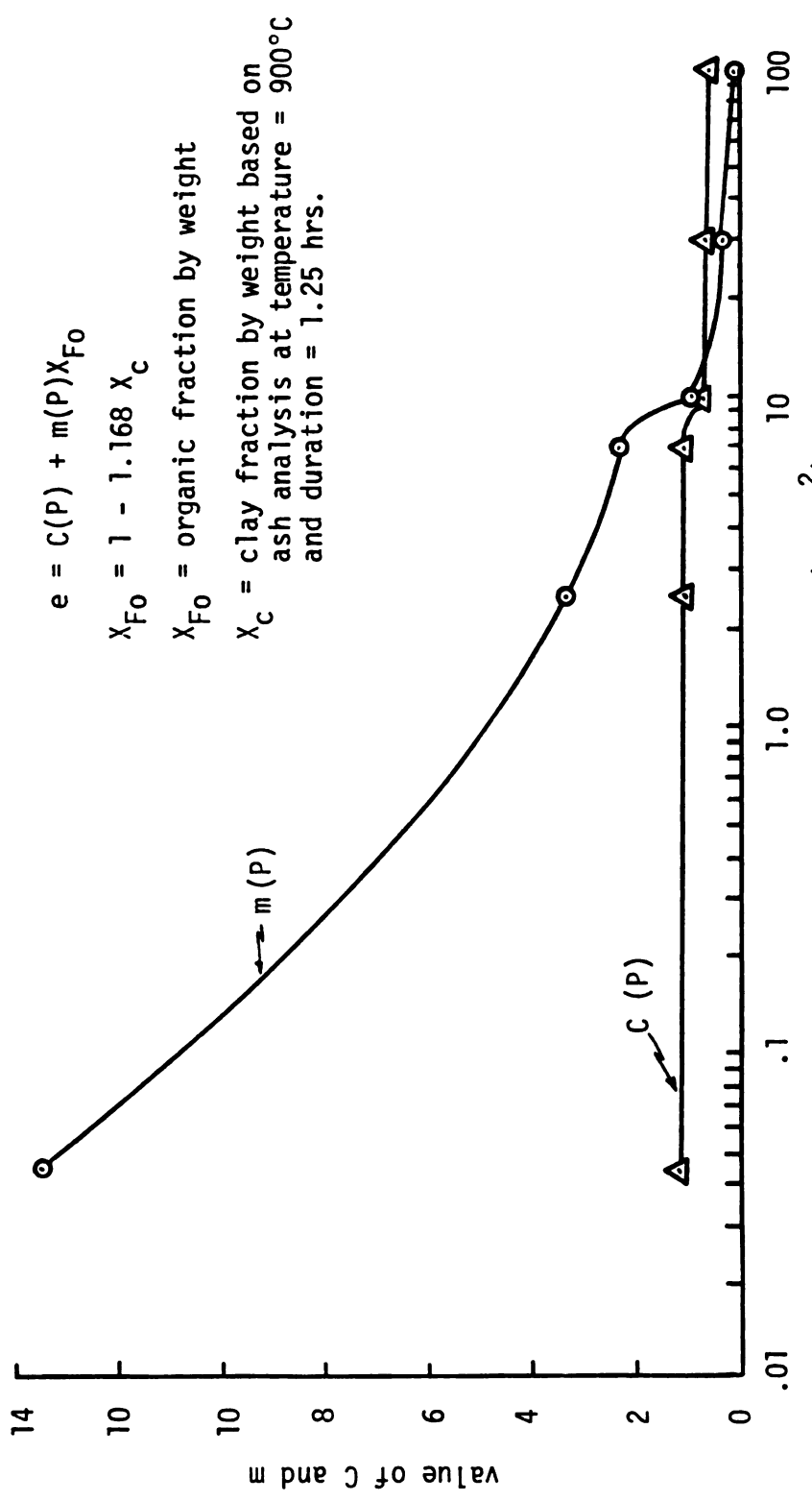


Figure 6.16.--Experimentally derived settlement parameters for organic soils.

$$\Delta H_\alpha = H_o \, C_\alpha \log \frac{t_2}{t_1} \qquad (6\text{-}25)$$

The experimental data included values for C_α ranging from 0.05 to 0.20 for undecomposed organic soil samples and from 0.10 to 0.50 for decomposed organic soil samples. Several examples are given to help illustrate application of the new method for ultimate consolidation settlement determination for organic soils.

Example 1. For a soil layer of thickness H_o = 10 ft., organic content X_{FO} = 30%, and initial overburden pressure P_o = 0.05 kg/cm^2, calculate the ultimate consolidation settlement for a stress increment of 0.95 kg/cm^2.

Solution. Use Equation 6-24:

$$e_o = C(P_o) + m\,(P_o)\, X_{FO}$$

from Fig. 6.16 for P_o = 0.05 read values for C and m, thus C(0.05) = 1.20 and m(0.05) = 13.70. Then for X_{FO} = 0.30

$$e_o = 1.2 + (13.7)(0.30) = 5.31$$

Following the same procedure determine e_1.

$$e_1 = C(P_1) + m(P_1)X_{FO}$$

where $P_1 = P_o + \Delta P = 0.05 + 0.95 = 1.0$ kg/cm^2 and $e_1 = C(1) + m(1)\, X_{FO} = 1.20 + (4.8)(0.30)$. Calculate the settlement using Equation 6-22:

$$\Delta H = \frac{H_0 (e_o - e_1)}{1 + e_o} = \frac{(10)(5.31 - 2.64)}{1 + 5.31} = 4.23 \text{ ft.}$$

Example 2. Same as example 1 except that $P_o = 1.0$ kg/cm^2 and a stress increment $\Delta P = 0.95$ kg/cm^2.

Solution. Using Fig. 6.16, read the intercept and slope coefficients and calculate e_o.

$$e_o = C\ (P_o) + m\ (P_o)\ X_{FO} = C\ (1) + m\ (1)\ X_{FO}$$

$$e_o = (1.20) + (4.8)(0.30) = 2.64$$

For the stress $P_1 = 1.00 + 0.95 = 1.95$ kg/cm^2, determine e_1

$$e_1 = C\ (P_1) + m\ (P_1)\ X_{FO} = C\ (1.95) + m\ (1.95)\ X_{FO}$$

$$e_1 = 1.20 + (3.70)(0.30) = 2.31.$$

Calculate the settlement

$$\Delta H = \frac{(10)(2.64 - 2.31)}{1 + 2.64} = 0.91 \text{ ft.}$$

This example illustrates the effect of the stress increment and the initial effective stress on the ultimate consolidation settlement. Note that the large difference in settlement for example 1 and 2 with the change in P_o. This is not the case for mineral soils.

Example 3. Same as example 1, except that $P_1 = P_o + \Delta P = 100$ kg/cm^2 and $X_{FO} = 100\%$. Also calculate the height of solids.

Solution. From Fig. 6.16, read values for C and m. Calculate:

$$e_o = C\ (0.05) + m\ (0.05)\ X_{FO} = 1.2 + (13.7)(1) = 14.9$$

and $$e_1 = C\ (100) + m\ (100)\ X_{FO} = 0.70 + 0\ (1) = 0.70$$

Calculate the settlement:

$$\Delta H = \frac{(10)\ (14.9 - 0.70)}{1 + 14.90} = 8.93 \text{ ft.}$$

The compressed height H_f = 10 - 8.93 ft. = 1.07 ft. To find the height of solids use the final void ratio $e_1 = e_f = 0.70$, and calculate H_s.

$$0.7 = \frac{H_f - H_S}{H_S} = \frac{1.07 - H_S}{H_S}$$

$$H_S = 0.63 \text{ ft.} < 1.07 \text{ ft.}$$

For a check on the accuracy of Fig. 6.16, use the initial void ratio and calculate H_s.

$$14.9 = \frac{H_o - H_S}{H_S} = \frac{10 - H_S}{H_S}$$

H_S = 0.63 which equals the previous value.

b. Ultimate settlement with decomposition: A major problem with organic soils is their potential decomposition. The decomposition of some or all of the organic matter results in a substantial settlement for organic soils deposits. Prediction of the settlement

due to decomposition requires information on the change in void ratios caused by removal of some or all of the organic matter under a constant overburden stress. The problem can be summarized as follows: (1) Given a soil layer of thickness H_o and initial organic content X_{FO} under an overburden stress of P_o, what is the amount of settlement that will occur due to the removal of organic solids by micro-organisms. (2) Since void ratio is dependent on the organic content, what amount of settlement will take place for a change in void ratio brought about by a decrease in organic content due to decomposition.

Derivation of equations needed to estimate the decomposition settlement are developed in a series of steps. Consider the following:

A. Given the initial organic content X_{FO} and overburden pressure P_o, determine the initial void ratio $e_o = C\ (P_o) + m\ (P_o)\ X_{FO}$ based on Equation 6-24.

B. Using e_o and the initial height of the decomposing layer H_o, calculate the initial height of solids H_{SO}.

$$e_o = \frac{H_o - H_{SO}}{H_{SO}}$$

$$H_{SO} = \frac{H_o}{1 + e_o} = H_{CO} + H_{FO} \qquad (6.26)$$

where H_{CO} is the initial mineral height and H_{FO} is the initial organic fraction height.

C. Use X_{FO} to find the initial mineral content.

$$X_{CO} = 1 - X_{FO} = \frac{W_{CO}}{W_{CO} + W_{FO}} \qquad (6\text{-}27)$$

where W_{co} is the initial mineral weight, and W_{FO} is the initial organic matter weight.

D. Express equation (6-27) in terms of the specific gravity of mineral solids (G_{sc}) and the organic matter (G_{sf}), H_{co}, and H_{fo}. Now solve for the initial mineral height H_{co}.

$$\frac{W_{CO}}{W_{CO} + W_{FO}} = \frac{\gamma_w A G_{SC} H_{CO}}{\gamma_w A G_{SC} H_{CO} + \gamma_w A G_{SF} H_{FO}} = X_{CO}$$

or $$X_{CO} = \frac{G_{SC} H_{CO}}{G_{SC} H_{CO} + G_{SF} H_{FO}}$$

where $G_{sc} = 2.70$ for minerals and $G_{sf} = 1.5$ for the organic material. Compute

$$H_{CO} = \frac{H_{FO} X_{CO}}{1.8 (1 - X_{CO})} \qquad (6\text{-}28)$$

E. Use H_{CO} and H_{SO} to calculate the initial organic fraction height (H_{FO}) by substituting equation (6-28) into equation (6-26).

$$H_{SO} = \frac{H_{FO} X_{CO}}{1.8 (1 - X_{CO})} + H_{FO}$$

$$H_{FO} = H_{SO} \frac{1 - X_{CO}}{1 - 0.44\ X_{CO}} = H_{SO} \frac{X_{FO}}{0.56 + 0.44\ X_{FO}}$$

$$H_{FO} = H_{SO}\ \psi$$

where $$\psi = \frac{X_{FO}}{0.56 + 0.44\ X_{FO}}$$

F. Use H_{FO} to calculate the decomposed height of the organic matter H_{FI}.

$$H_{FI} = (1 - X_{DI})\ H_{FO} \qquad (6.27)$$

G. Given X_{DI}, calculate the organic content of the decomposed soil layer X_{FI} using equation (4-15)

$$X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$$

or $$X_{FI} = \frac{X_{FO}\ (1 - X_{DI})}{(1 - X_{DI}X_{FO})}$$

H. Now, calculate the final void ratio e_f using X_{FI} and Equation (6-24).

$$e_f = C(P_o) + m\ (P_o)\ X_{FI}$$

I. Using e_f, X_{DI}, H_{FI}, and H_{CO}, calculate the decomposed layer height H_D. Recall that

$$e_f = \frac{H_D - H_{SI}}{H_{SI}} = \frac{H_D - H_{CO} - H_{FI}}{H_{CO} + H_{FI}} \qquad (6\text{-}28)$$

substitute equation (6-27) into equation (6-28) and solve for H_D.

$$H_D = [(1 - X_{DI})H_{FO} + H_{CO}](1 + e_f)$$

or $H_D = [(1 - X_{DI})\ H_{FO} + H_{SO} - H_{FO}](1 + e_f)$

Recall that $H_{FO} = \psi H_{SO}$, hence

$$H_D = [(1 - X_{DI})\ H_{SO}\ \psi + H_{SO} - \psi\ H_{SO}](1 + e_f).$$

Rearrangement gives

$$H_D = [(1 - X_{DI})\ \psi + 1 - \psi]\ H_{SO}\ (1 + e_f)$$

$$H_D = [\psi - \psi\ X_{DI} + 1 - \psi]\ H_{SO}\ (1 + e_f)$$

$$H_D = (1 - \psi\ X_{DI})(1 + e_f)\ H_{SO} \qquad (6\text{-}29)$$

Substituting equation (6-26) into equation (6-29) gives:

$$H_D = \left(\frac{1 + e_f}{1 + e_o}\right)\ (1 - \psi\ X_{DI})\ H_O \qquad (6\text{-}30)$$

J. The settlement due to loss of solids and the change in void ratio due to decomposition can now be calculated as

$$\Delta H_D = H_o - H_D \qquad (6\text{-}31)$$

Note that Equations (6-30) and (6-31) determine the settlement due to decomposition only, if there is a stress increment, then additional settlement will occur. The solution to this problem was outlined earlier. In order to illustrate the method, consider the following examples.

Example 1. A soil layer with H_o = 10 ft., X_{FO} = 30% and P_o at depth 5 ft. equal to 0.10 kg/cm^2 has undergone 20% decomposition (X_{DI}). Calculate the settlement ΔH_D.

Solution. Use Equation 6-24 to calculate the initial void ratio e_o.

$$e_o = C(P_o) + m\,(P_o)\,X_{FO} = C\,(1) + m\,(1)\,X_{FO}$$

From Fig. 6.13 read C(1) = 1.2, m(1) = 10.80 and e_o = 1.2 + (10.80)(0.30) = 4.44. Use the same procedure to calculate the final void ratio e_f.

$$e_f = C(1) + m(1)\,X_{FI} = 1.2 + 10.80\,X_{FI}$$

where $X_{FI} = \dfrac{X_{FO}\,(1 - X_{DI})}{1 - X_{DI}\,X_{FO}} = \dfrac{(0.3)(1 - 0.20)}{1 - (0.2)(0.3)} = 25.53\%$

and $e_f = (1.2) + (10.80)(0.2553) = 3.96.$

$$\psi = \frac{X_{FO}}{(0.56 + 0.44\ X_{FO})} = \frac{0.30}{(0.56) + (0.44)(0.30)} = 0.47$$

and $$HD = \left(\frac{1 + e_f}{1 + e_o}\right)(1 - KX_{DI})\ H_o$$

$$H_D = \left(\frac{1 + 3.96}{1 + 4.44}\right)(1 - (0.47)(0.20)(10') = 8.25 \text{ ft.}$$

Compute the settlement due to decomposition

$$\Delta H_D = H_o - H_D = 10 - 8.25 = 1.75 \text{ ft.}$$

Example 2. Same as Example 1 except that the overburden stress $P_o = 100\ kg/cm^2$.

Solution. Compute the initial and final void ratios as before.

$$e_o = C\ (100) + m\ (100)\ X_{FO} = (0.70) + (0)(0.3) = 0.70$$

$$e_f = C\ (100) + m\ (100)\ X_{FI} = (0.7) + (0)(X_{FI}) = 0.70$$

Note that at this stress level there will be no change in void ratio (Fig. 6.15) but settlement will still occur due to the loss of organic matter. Compute

$$\psi = \frac{0.3}{0.56 + (6.44)(0.30)} = 0.47$$

and $$H_D = \left(\frac{1 + 0.7}{1 + 0.7}\right)(1 - (0.47)(0.20))(10) = 9.06 \text{ ft.}$$

Calculate the settlement $\Delta H_D = 10 - 9.06 = 0.94$ ft. This result shows that at high stress levels, there will be less settlement due to decomposition of organic solids.

Example 3. An organic soil with $H_o = 10$ ft., $X_{FO} = 20\%$ and initial overburden of 5 ft. with $P_o = 1$ kg/cm^2 has been subjected to a stress increment of 1 kg/cm^2. Calculate the total settlement if 30% decomposition is anticipated in the field.

Solution. Compute the initial and final void ratios as before.

$$e_o = C\,(1) + m\,(1)\,X_{FO} = 1.2 + (4.8)(0.2) = 2.16$$

$$e_f = 1.2 + 3.8\,X_{FI}$$

Where $$X_{FI} = \frac{(0.20)(1 - 0.3)}{1 - (0.2)(0.3)} = 14.58\%$$

$$e_f = 1.90$$

Compute

$$\psi = \frac{0.2}{0.56 + (0.44)(0.20)} = 0.31$$

and $$H_D = \frac{(1 + 1.90)}{(1 + 2.16)}\,[1 - (0.3)(0.31)]\,10 = 8.32 \text{ ft.}$$

Calculate the settlement due to decomposition.

$$\Delta H_D = 10 - 8.32 = 1.68 \text{ ft.}$$

Consider next the settlement due to the load increment.

$$e_o = C\,(1) + m\,(1)\,X_{FI} = 1.2 + 4.8\,X\,\cdot\,1458 = 1.90$$

For the stress increment $\Delta p = 2.0\ kg/cm^2$

$$p_1 = P_o + \Delta p = 1 + 2 = 3.0\ kg/cm^2$$

$$e_1 = C\,(P_1) + m\,(P_1)\,X_{FI} = C\,(3) + m\,(3)\,X_{FI}$$

$$e_1 = 1.19 + 3.08\,X_{FI} = 1.19 + (3.08)(.1485) = 0.54$$

Calculate the settlement due to consolidation.

$$\Delta H_c = \frac{H_D\,(e_1 - e_o)}{1 + e_o} = \frac{(8.32)(1.90 - 0.54)}{1 + 1.90}$$

$$\Delta H_c = 3.89\ ft.$$

The total ultimate settlement due to consolidation and decomposition

$$\Delta H = \Delta H_c + \Delta H_D = 3.89 + 1.68 = 5.57\ ft.$$

D. Vane Shear Strength

The problem of correctly assessing the shearing resistance of a given soil is one of the most complex in geotechnical engineering. Organic soils are no exception. Their compressibility characteristics, stress-strain behavior, and potential decomposition add new dimensions to the problem of predicting their shear strength. Unlike mineral soils their shear strength appears to increase with increasing deviatoric stress for strains in excess of 20%. Using a miniature vane shear apparatus, a direct measurement of undrained shear

strength was obtained under different consolidation pressures over a range of organic contents and C/N ratios.

The initial shear strength for different samples was plotted against organic content in Fig. 5.18. For a given consolidation pressure the undrained shear strength increases for higher organic contents. This trend agrees with experimental work by Khattak, (1978). A limitation of the vane shear apparatus (section 4-E) is that the vane size used may influence the shear strength predicted for a given soil (MacFarlane, 1969). Fortunately, the objectives in this test program were not meant to provide absolute values, but rather relative values of shear strength with respect to change in organic content due to decomposition. This objective was realized using constant test conditions, i.e., the same consolidation pressures and vane size. The vane shear strength was influenced by pH, i.e., hydrogen ion concentration (Fig. 5.26). The shear strength increased from a low at pH = 5.7 to a high at pH = 7.0, then dropped to another low at pH > 7.0. This behavior was observed at organic contents of 30, 60, and 80% (Fig. 5.26). The explanation for these test results may be due to differences in the pore fluid viscosity and attractive forces between the soil particles for pH values above or below 7.0. Greater repulsive forces between particles for pH values above or below 7.0 would alter the equilibrium stress levels for a given consolidation stress and thereby reduce the degree of consolidation. This effect would result in different undrained shear strengths.

The undrained shear strength was also studied in terms of nutrient contents for organic contents of 30, 60, and 80% (Fig. 5.25). This figure shows that samples having low nutrient contents, i.e., high initial C/N ratios, exhibited a higher shearing strength for a given consolidation pressure. Reasons similar to those related to pH may be the cause of this behavior. Higher shear strengths were also observed for higher organic contents as shown in Fig. 5.18. Greater reinforcement due to interlocking between fibers would contribute to this strength increase.

Aerobic and anaerobic decomposition processes produced a very significant effect on the undrained shear strength of the fiber/kaolinite soil mixtures as shown by Fig. 5.35 and 5.42. The shear strength decreased by approximately 75% for a 55% average degree of decomposition. This drop in shear strength could have major effects on the stability of organic soil slopes. If the organic fibers are considered as reinforcing elements, then the disappearance of this reinforcement due to decomposition would undoubtedly reduce the shear strength of these soils. The degree of fiber breakdown would then be viewed as the major factor in determining the magnitude of strength reduction. In order to eliminate the influence of C/N ratios, samples having a C/N = 30 were used in Stage-3 to study the effect of decomposition on shear strength as shown in Fig. 5.50. The trend continues with a greater decrease in shear strength with larger degrees of decomposition irrespective of the consolidation pressure, organic content, or nutrient content.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A brief review followed by conclusions pertinent to each area is presented under six headings: Organic Content, Decomposition, Physical Parameters, Consolidation Behavior and Settlement, Vane Shear Strength, and Needed Future Research.

A. Organic Content

Using a numerical procedure combined with thermal characteristic curves for kaolinite, montmorillonite, and cellulose, much of the error (approximately 15%) encountered in the standard ash content method for determination of organic content was eliminated. This modified procedure was adopted for the entire test program.

1. Use of dehydration curves for kaolinite and montmorillonite made possible the elimination of a large part of the errors associated with the ash content method for organic content determination. Using appropriate coefficients and the solution of linear equations, organic content of soils with known mineral types were determined to an accuracy close to ±1%.

2. Using a burning duration of 12 hours, the organic content of most soils can be determined within ±1% irrespective of the type

of mineral or organic fractions through the solution of two linear equations.

3. The organic content of soil was redefined as the ratio of combustable soil weight, at temperatures higher than 100°C, minus the weight lost due to dehydration to the initial oven dry (100°C) weight.

B. Decomposition (Aerobic and Anaerobic)

Decomposition was induced in laboratory prepared samples under both aerobic and anaerobic conditions. Samples were supplied with nutrients in proportions similar to those found in an average bacterial cell. This approach permitted decomposition of the organic fibers by micro-organisms using the cellulose and nutrients as their food source.

1. The percent decomposition X_{DI} of organic material was determined in terms of the initial (W_{FO}) and final (W_{FI}) organic weights, thus $X_{DI} = (\frac{W_{FO} - W_{FI}}{W_{FO}})(100)$. The nature of the decomposition process added new complications since organic matter includes bacterial cells which are formed as a result of decomposition. Therefore, the cell yield was included in determining decomposition.

2. Using McCarty's model for cell yield (y) prediction, y was found to be approximately 20 gms of cells per 100 gms of organic substrate under aerobic conditions and 10 gms of cells per 100 gms of organic substrate under anaerobic conditions.

3. A mathematical expression which takes into account the cell yield for a given degree of decomposition was formulated. The

percent decomposition was found to be inversely proportional to the quantity (1 - y). No values for cell yield (y) were used since additional research is needed for verifying the mathematically obtained estimates of (y). Nevertheless, the expression provides all the tools needed for predicting the exact magnitude of decomposition once a reasonable (y) is determined.

4. The maximum observed degree of decomposition was approximately 75% for the anaerobic samples and 85% for the aerobic. The carbon/nitrogen ratio (C/N) at which these values occurred ranged from 20:1 to 30:1 and was dependent on the initial organic content of these soils.

5. The nitrogen nutrient source has a definite effect on the ultimate degree of decomposition attained. Ammonium chloride was rated superior to ammonium sulfate in inducing greater degrees of decomposition.

6. Decomposition was dependent not only on the amount of nitrogen expressed in terms of the C/N ratio, but also on the other nutrients. Phosphorous, calcium, potassium, magnesium, sodium, and iron provided the other elements needed for the decomposition processes.

7. Nutrient amounts in excess of the optimum C/N ratio were toxic to the micro-organisms. This was exhibited by lower rates and amounts of decomposition. This phenomenon becomes important when decomposition is purposely induced in actual field deposits. Too much nutrient will cost more and yet do less in the way of decomposing the organic fraction.

8. Nutrient amounts below the optimum C/N ratio resulted in nutritional deficiencies with reduced rates of decomposition. Too much or too little nutrient will result in failure to decompose the organic material. Optimum results were obtained with the following ratios: C/N = 30, P/N = 1/6, and (Mg, Na, Ca, Fe)/N = 1/15.

9. The aerobic decomposition process was cleaner with practically no odor; on the other hand, the anaerobic process produced various gases as a result of volatile acids produced.

10. An electron scanning microscope provided photographic evidence of the change in structural integrity of a given fiber with increasing degrees of decomposition due to microbial activity. A complete fiber breakdown with reduction in length, diameter, and a rougher surface were predominant features observed.

C. Physical Parameters

Physical properties of the organic soils studied included specific gravity, liquid limit, moisture content, and permeability.

1. An improved mathematical expression for computing the specific gravity for combinations of mineral solids and organic matter helped increase the accuracy of all volumetric computations. The error (up to 18%) associated with the linear function presented in the literature has been eliminated.

2. An equivalent liquid limit, defined as the moisture content corresponding to 25 gm/cm^2 shearing strength, increased with higher organic fiber content. Problems encountered with fibers

interfering with the standard test procedure were avoided. Decomposition reduced the equivalent liquid limit to about 40% of its initial value.

3. Unlike mineral soils, the relationship between water content and logarithm of stress for organic soils is not a simple linear function. The moisture content ranged from 1,000% for 80% organic material by weight to 350% for 30% organic material by weight at a consolidation pressure of 0.006 gm/cm^2. Higher stress levels reduced the moisture content by substantial amounts.

4. Fibrous organic soils are highly permeable; however, this permeability is influenced by both the organic content and stress level. Low permeabilities are associated with high stress levels, low organic contents, or both. Under a given consolidation pressure, permeability shows a large decrease with decomposition.

D. Consolidation Behavior and Settlement

A modified consolidation procedure was developed based on numerous tests on organic soil samples at various stages of decomposition. Effects of different organic contents, decomposition, and nutrient combinations were observed relative to conventional consolidation parameters.

1. Nutrient levels expressed in terms of C/N, P/N, and other ratios, have a significant effect on the rate of consolidation. High nutrient concentrations in general reduced the coefficient of consolidation.

2. The compression index ranged from 2 to 6 for organic contents of 30% and 80% by weight respectively, with no decomposition and a stress increment of 0.006 to 0.046 kg/cm^2. The compression index increased to more than twice its initial value at approximately 20% decomposition. This was followed by a decrease to or below its initial value for complete decomposition.

3. Use of the compression index for prediction of ultimate settlements in organic soils must be limited to a given soil (constant organic content) and small stress increments. Change in either organic content or larger stresses both alter the compression index so as to seriously limit its application to ultimate settlement calculations.

4. For the same stress level the coefficient of consolidation c_v increased with higher organic contents, decreased with the addition of nutrients, and decreased by a factor of up to 2×10^5 with 50% decomposition of organic matter. Increase in stress level produces a decrease in the coefficient of consolidation.

5. The void ratio at a stress level of 0.006 kg/cm^2 ranged from 8 to 14 for 30% and 80% organic content, respectively. Gases produced as a by-product of the decomposition process increased the void ratio for all organic contents, the amount dependent on the degree of decomposition and any escape of gases.

6. Both aerobic and anaerobic decomposition processes influenced the consolidation parameters of samples studied. Generally, the degree to which a given parameter was altered would be

determined more by the degree of decomposition rather than the type of decomposition process.

7. The relationship between void ratio and organic content for a constant stress level was found to be linear. Each stress level gave a specific intercept (C) and slope (m) which when plotted gave the relationships summarized in Fig. 6.16. Use of this figure, the stress level P, and the organic fraction by weight, X_{FO}, permitted computation of the void ratio,

$$e = C(P) + m(P)\ X_{FO} \qquad (6\text{-}24)$$

for all organic soils used in this test program.

8. Ultimate settlement computation for organic soil deposits with little or no decomposition can now be made using equation (6-24) to compute initial and final void ratios. The settlement is then a function of soil layer thickness H_o, the initial void ratio e_o, and the change in void ratio Δe, thus

$$\Delta H = H_o \frac{\Delta e}{1 + e_o}$$

9. Ultimate settlement in partially decomposed organic soils will include consolidation settlement, settlement due to loss of solids, and secondary compression. The consolidation settlement can be computed using Fig. 6.16 and equation (6-24) when information on the initial and final organic contents are known. Settlement due to loss of solids may be computed with equations (6-30) and (6-31)

using information on the initial organic content, the percent decomposition, initial and final void ratios, and the initial soil layer thickness. Secondary compression would be computed by conventional methods.

10. The coefficient of secondary compression C_α was observed to be relatively independent of the organic content and the level of decomposition. More data are needed to fully explore the effects of decomposition on C_α.

E. Vane Shear Strength

A miniature vane 1/2 inch in diameter by 1.0 inch in height was used to determine the undrained shear strength of fibrous organic soil samples at selected stress levels and various stages of decomposition.

1. The undrained shear strength of a soil at a given stress level increased with higher organic contents. Higher degrees of consolidation resulted in higher undrained strengths irrespective of the organic content.

2. The addition of nutrients to the fresh kaolinite/fiber soil mixtures reduced the undrained shear strength for all organic contents under a given consolidation pressure.

3. Both aerobic and anaerobic decomposition of the soil organic material led to a large decrease in the undrained shear strengths measured for a given consolidation pressure. For 55% decomposition the decrease in shear strength was close to 80%. This large decrease in strength has a major significance relative to existing and future high ash papermill sludge deposits.

4. The undrained shear strength after decomposition is dependent on the initial organic content and the degree of decomposition. The difference may be small and of little importance when dealing with relatively high organic content soils.

E. Needed Future Research

Information developed by this research project has raised a number of interesting questions. A few of these problems are summarized in the following paragraphs.

1. Cell yield--Since part of the decomposed organic matter in a given soil will be converted to organic microbial cells, it is obvious that the organic content and hence percent decomposition of that soil will err by a factor dependent on the cell content of the mass undergoing decomposition. A mathematical expression which takes into account the cell yield (y) was developed. The task remaining is to determine a reasonable value for (y) under both aerobic and anaerobic conditions.

2. Gas effects--Probably one of the most poorly understood areas concerning organic soils is that of gases present in the medium and its effects on the engineering parameters. A systematic approach must be applied to isolate these effects and their significance relative to general organic soil behavior. This research gave some clues as to what can be expected. The significant increase in compressibility due to presence of gas illustrates one of the effects.

3. High stress levels--Organic soils experience significant changes in their behavior depending on the stress level. Under

biologically stable conditions (no-decomposition) considerable information is available. This research dealt primarily with decomposing organic soils at low stress levels. Additional research is needed to determine the effect of higher stress levels on the engineering behavior of decomposing soils.

4. Field behavior--The current study dealt with laboratory behavior of model organic soils prepared from kaolinite and pulp fiber. Field behavior should be investigated in order to verify laboratory studies. Does variability of field temperatures as compared to constant laboratory temperatures play an important role in soil behavior, mechanical and biological? To initiate and support field decomposition can nutrients be added through the use of infiltration techniques.

5. Nonfibrous organic soils--Many soil deposits may contain organic matter which is not fibrous. Some peat soils are examples. Research should be conducted to determine if the type of the organic matter has any relationship to the engineering behavior of that soil.

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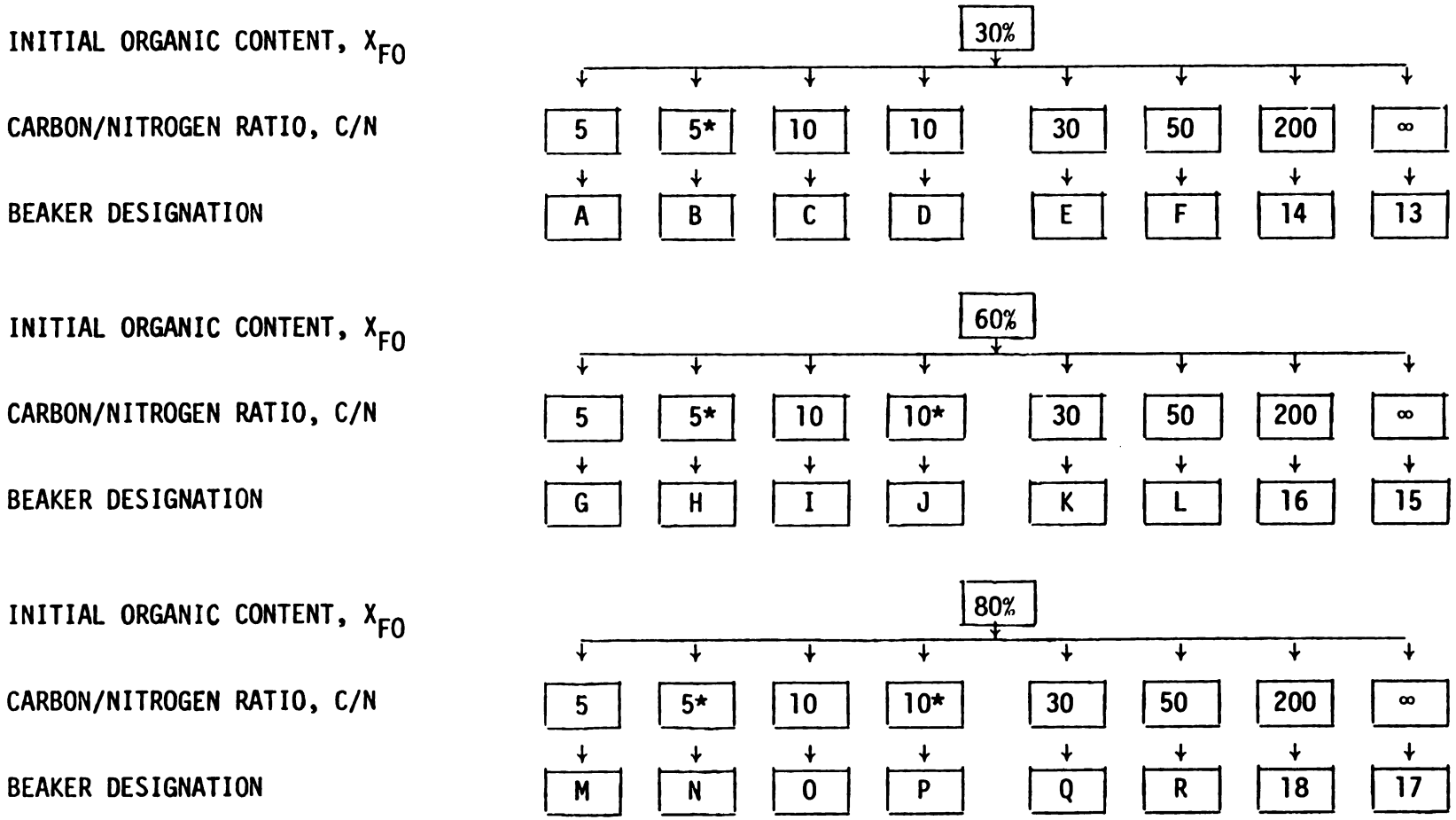
APPENDICES

APPENDIX A

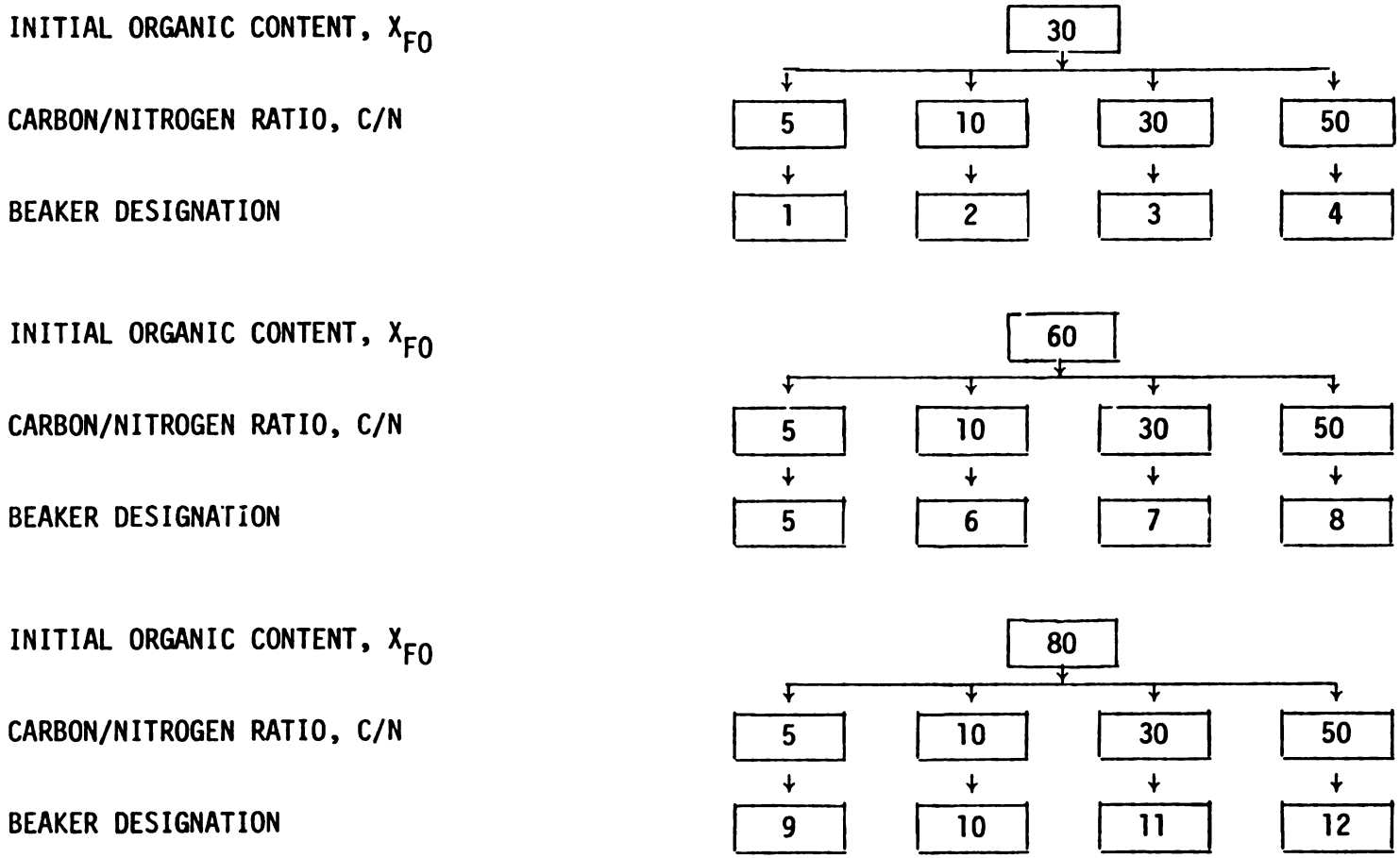
TESTS, SYMBOLS, AND SAMPLE PREPARATION

TABLE A-0.--Block Diagram, Anaerobic, Stage I (Initial Conditions)



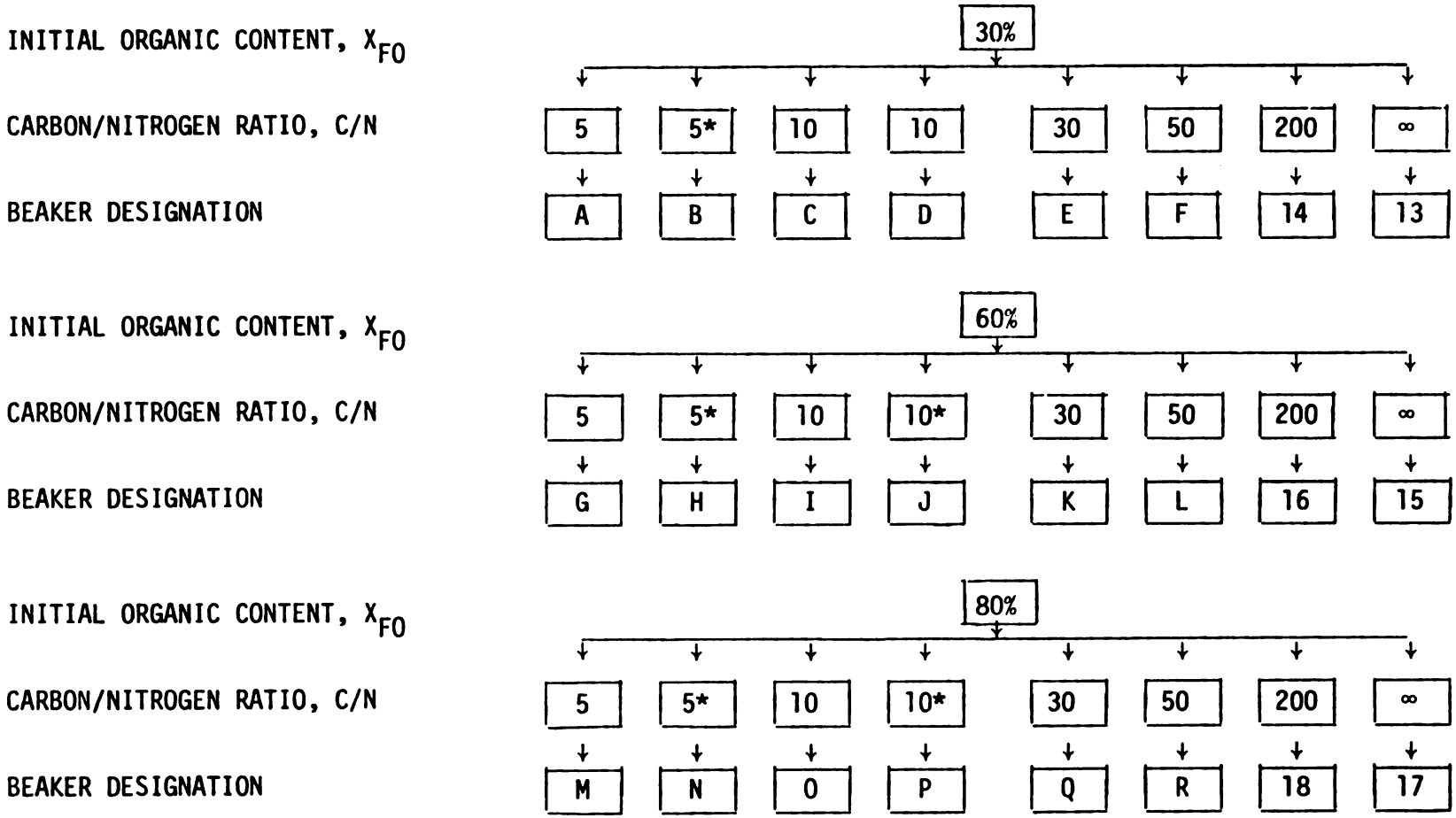
*Ammonium sulfate used as nitrogen source (ammonium chloride used on all others).

TABLE A-0.--Block Diagram, Aerobic, Stage I (Initial Conditions).



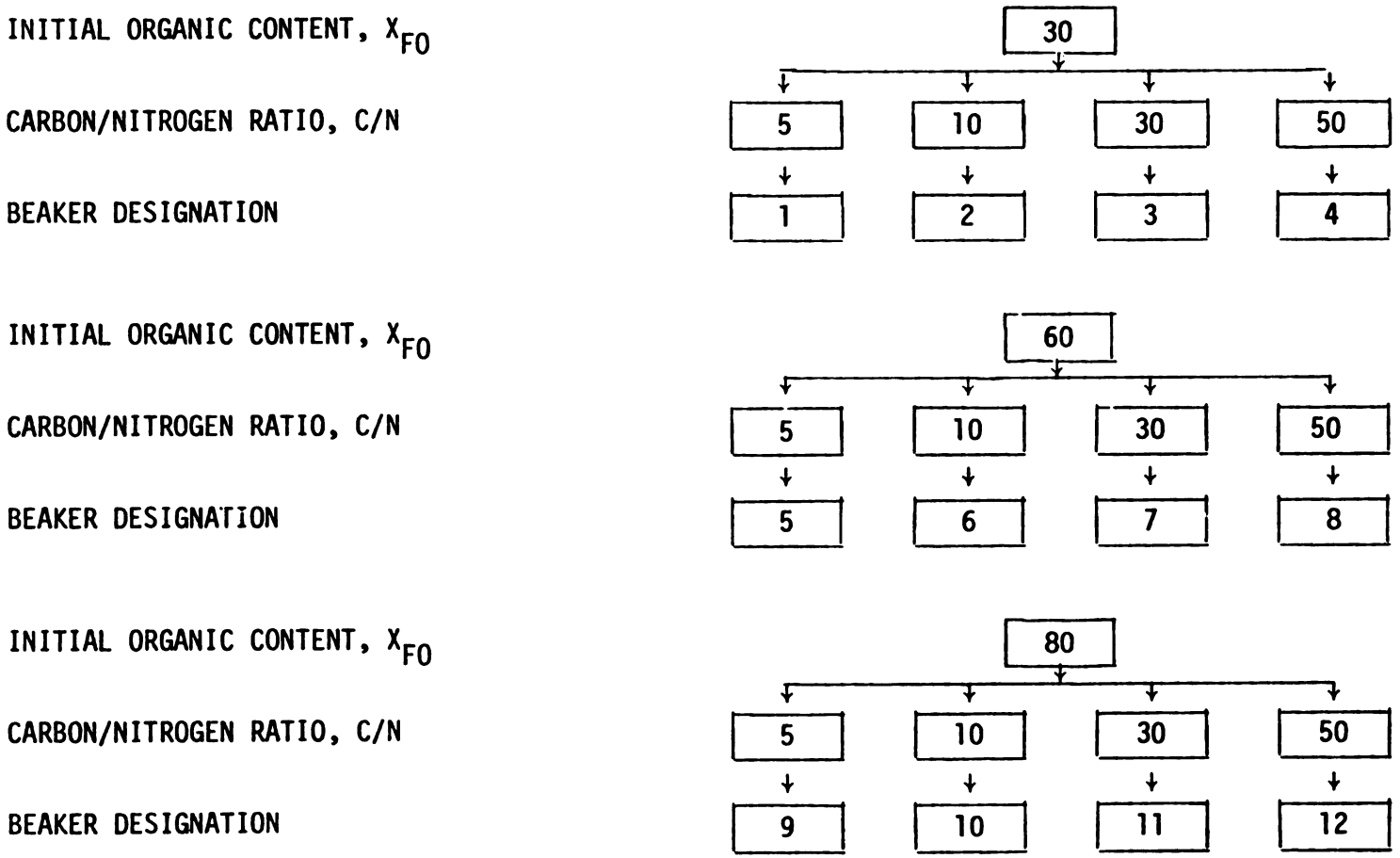
* Ammonium chloride used as nitrogen source for all beakers.

TABLE A-O.--Block Diagram, Anaerobic, Stage II (Final Condition)



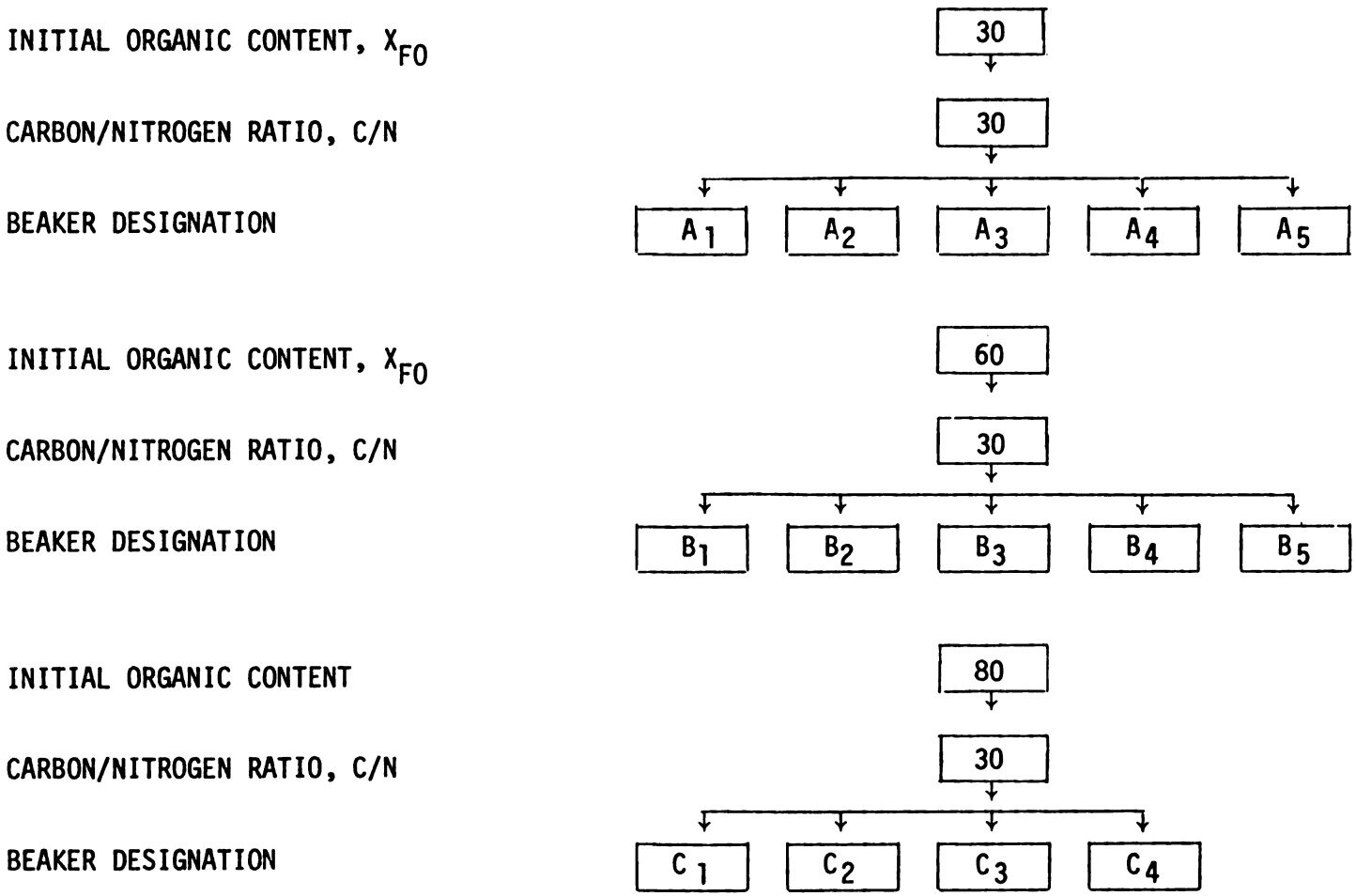
*Ammonium sulfate used as nitrogen source (ammonium chloride used on all others).

TABLE A-0.--Block Diagram, Aerobic, Stage II (Final Conditions).



* Ammonium chloride used as nitrogen source for all beakers.

TABLE A-0.--Block Diagram, Anaerobic, Stage III.



*Samples were tested after 0, 1, 2, 3, 5, and 7 weeks of decomposition.

TABLE A-1.--Sample Preparation and General Information.

Beaker	A		B		C		D	
Cellulose Content (nutrient free) by weight	30%		30%		30%		30%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	5:1		5:1		10:1		10:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	150	25.92	150	25.40	150	27.68	150	27.38
Clay	350	60.49	350	59.40	350	64.59	350	63.88
Water	2534	-	2534	-	2534	-	2399.8	-
$(NH_4)_2SO_4$	-	-	62.89	10.70	-	-	31.45	5.74
$MgSO_4$	4.40	0.76	4.40	0.74	2.20	0.41	2.20	0.40
$FeCl_3$	2.48	0.45	2.58	0.44	1.29	0.24	1.29	0.24
K_2HPO_4	12.50	2.16	12.50	2.12	6.25	1.15	6.25	1.14
$CaCl_2$	2.46	0.43	2.46	0.42	1.23	0.23	1.23	0.22
Seeding Material	5.78	1.00	5.90	1.00	5.42	1.00	5.48	1.00
NH_4CL	50.90	8.80	-	-	25.45	4.70	0	0
Total	3112.62	100	3124.73	100	3975.84	100	2947.7	100

TABLE A-1.--Sample Preparation and General Information. (Continue 1)

Beaker	E		F		G		H	
Cellulose Content (nutrient free) by weight	30%		30%		60%		60%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	30:1		50:1		5:1		5:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	150	29.00	150	29.27	187.5	46.00	187.5	44.35
Clay	350	67.66	350	68.30	125	30.66	125	29.57
Water	2264	-	2244	-	2487	-	2578	-
$(NH_4)_2SO_4$	-	-	-	-	-	-	78.61	18.59
$MgSO_4$	0.73	0.14	0.44	0.09	5.50	1.35	5.50	1.30
$FeCl_3$	0.43	0.08	0.26	0.05	3.23	0.79	3.23	0.76
K_2HPO_4	2.08	0.40	1.25	0.24	15.62	3.83	15.62	3.69
$CaCl_2$	0.41	0.08	0.25	0.05	3.08	0.76	3.08	0.73
Seeding Material	5.17	1.00	5.12	1.00	4.08	1.00	4.23	1.00
NH_4CL	8.48	1.64	5.09	0.99	63.63	15.61	-	-
Total	3781.3	100	2756.41	100	2894.64	100	3000.77	100

TABLE A-1.--Sample Preparation and General Information. (Continue 2)

Beaker	I		J		K		L	
Cellulose Content (nutrient free) by weight	60%		60%		60%		60%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	10:1		10:1		30:1		50:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	187.5	51.85	187.5	50.78	187.5	56.65	187.5	57.72
Clay	125	34.56	125	33.86	125	37.76	125	38.48
Water	2206	-	2252	-	2019	-	1982	-
$(NH_4)_2SO_4$	-	-	39.30	10.64	-	-	-	-
$MgSO_4$	2.75	0.76	2.75	0.74	0.92	0.28	0.55	0.17
$FeCl_3$	1.61	0.45	1.61	0.44	0.54	0.16	0.32	0.10
K_2HPO_4	7.81	2.16	7.81	2.12	2.60	0.79	1.56	0.48
$CaCl_2$	1.54	0.43	1.54	0.42	0.51	0.15	0.31	0.10
Seeding Material	3.62	1.00	3.69	1.00	3.31	1.00	3.25	1.00
NH_4CL	31.82	8.80	-	-	10.61	3.21	6.36	1.96
Total	2567.65	100	2621.20	100	2349.99	100	2306.85	100

TABLE A-1.--Sample Preparation and General Information. (Continue 3)

Beaker	M		N		O		P	
Cellulose Content (nutrient free) by weight	80%		80%		80%		80%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	5:1		5:1		10:1		10:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	180	57.05	180	54.01	180	66.32	180	64.59
Clay	45	14.26	45	13.50	45	16.58	45	16.15
Water	2650	-	2799.55	-	2280	-	2344	-
$(NH_4)_2SO_4$	-	-	75.45	22.64	-	-	37.73	13.54
$MgSO_4$	5.28	1.67	5.28	1.58	2.64	0.97	2.64	0.95
$FeCl_3$	3.10	0.98	3.10	0.93	1.55	0.57	0.55	0.56
K_2HPO_4	15.00	4.75	15.00	4.50	7.50	2.76	7.50	2.69
$CaCl_2$	2.95	0.93	2.95	0.89	1.48	0.55	1.48	0.53
Seeding Material	3.16	1.00	3.33	1.00	2.71	1.00	2.79	1.00
NH_4CL	61.09	19.36	-	-	30.54	11.25	-	-
Total	2965.58	100	3129.67	100	2551.42	100	2622.69	100

TABLE A-1.--Sample Preparation and General Information. (Continue 4)

Beaker	Q		R		13		14	
Cellulose Content (nutrient free) by weight	80%		80%		30%		30%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	30:1		50:1		∞		200	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	180	75.13	180	76.24	150	30	150	29.48
Clay	45	18.78	45	19.06	350	70	350	68.78
Water	2032	-	1983	-	2190	-	2198	-
$(NH_4)_2SO_4$	-	-	-	-	-	-	-	-
$MgSO_4$	0.88	0.37	0.53	0.22	-	-	0.11	.02
$FeCl_3$	0.52	0.22	0.31	0.13	-	-	0.07	.01
K_2HPO_4	2.50	1.04	1.50	0.64	-	-	0.31	.06
$CaCl_2$	0.49	0.20	0.30	0.13	-	-	2.06	.40
Seeding Material	2.42	1.00	2.36	1.00	-	-	5.02	.99
NH_4CL	10.18	4.25	6.11	2.59	-	-	1.27	.25
Total	2273.99	100	2219.11	100	2690.00	100	2706.84	100

TABLE A-1.--Sample Preparation and General Information. (Continue 5)

Beaker	15		16		17		18	
Cellulose Content (nutrient free) by weight	60%		60%		80%		80%	
Seeding Material	Sludge		Sludge		Sludge		Sludge	
C/N	∞		200		∞		200	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry
Cellulose	187.6	60	187.5	58.97	180	80	180	78.44
Clay	125.0	40	125.0	39.32	45	20	45	19.61
Water	1906	-	1923	-	1890	-	1908	-
$(NH_4)_2SO_4$	-	-	-	-	-	-	-	-
$MgSO_4$	-	-	0.14	.04	-	-	0.13	.06
$FeCl_3$	-	-	0.09	.03	-	-	0.09	.04
K_2HPO_4	-	-	0.39	.12	-	-	0.37	.16
$CaCl_2$	-	-	0.08	.03	-	-	0.08	.03
Seeding Material	-	-	3.15	1.00	-	-	2.27	1.00
NH_4CL	-	-	1.59	.50	-	-	1.53	.67
Total	2218.5	100	2240.94	100	2115.00	100	2137.47	100

TABLE A-1.--Sample Preparation and General Information. (Continue 6)

Beaker	1		2		3		4	
Cellulose Content (nutrient free) by weight	30%		30%		30%		30%	
Seeding Material	Garden Soil		Garden Soil		Garden Soil		Garden Soil	
C/N	5:1		10:1		30:1		50:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**	**Wt.(g)**	**% Dry**
Cellulose	225	24.88	225	26.83	225	28.30	225	28.61
Clay	525	58.05	525	62.60	525	66.03	525	66.77
Water	1682.13	-	1560	-	1479	-	1463	-
$(NH_4)_2SO_4$	94.33	10.43	47.17	5.62	15.72	1.98	9.43	1.20
$MgSO_4$	6.60	0.73	3.30	0.39	1.10	0.14	0.66	0.08
$FeCl_3$	3.87	0.43	1.94	0.23	0.65	0.08	0.39	0.05
K_2HPO_4	18.75	2.07	9.37	1.12	3.12	0.39	1.87	0.24
$CaCl_2$	3.69	0.41	1.85	0.22	0.62	0.07	0.37	0.05
Seeding Material	27.13	3.00	25.16	3.00	23.85	3.00	23.57	3.00
NH_4CL	-	-	-	-	-	-	-	-
Total	2586.5	100	2398.79	100	2274.06	100	2249.31	100

TABLE A-1.--Sample Preparation and General Information. (Continue 7)

Beaker	5		6		7		8	
Cellulose Content (nutrient free) by weight	60%		60%		60%		60%	
Seeding Material	Garden Soil		Garden Soil		Garden Soil		Garden Soil	
C/N	5:1		10:1		30:1		50:1	
P/N	1:6		1:5		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry
Cellulose	300	44.80	300	49.76	300	55.08	300	58.03
Clay	200	29.87	200	33.17	200	36.77	200	38.69
Water	1245.5	-	1121	-	1013	-	991.30	-
$(NH_4)_2SO_4$	125.77	18.78	62.89	10.43	20.96	3.85	12.58	2.43
$MgSO_4$	8.80	1.31	4.40	0.73	1.47	0.27	0.88	0.17
$FeCl_3$	5.16	0.77	2.58	0.43	0.86	0.16	0.52	0.10
K_2HPO_4	24.99	3.73	12.50	2.07	4.17	0.77	2.50	0.48
$CaCl_2$	4.92	0.73	2.46	0.41	0.82	0.16	0.49	0.09
Seeding Material	20.71	3.00	18.09	3.00	16.34	3.00	15.99	3.00
NH_4CL	-	-	-	-	-	-	-	-
Total	1935.85	100	1723.92	100	1557.62	100	1524.26	100

TABLE A-1.--Sample Preparation and General Information. (Continue 8)

Beaker	9		10		11		12	
Cellulose Content (nutrient free) by weight	80%		80%		80%		80%	
Seeding Material	Garden Soil		Garden Soil		Garden Soil		Garden Soil	
C/N	5:1		10:1		30:1		50:1	
P/N	1:6		1:6		1:6		1:6	
(Mg, Fe, K, Ca, Na)/N	1:15		1:15		1:15		1:15	
Compounds	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry	Wt.(g)	% Dry
Cellulose	280	53.43	280	63.80	280	72.16	280	74.24
Clay	70	13.36	70	15.82	70	18,04	70	18.56
Water	974.76	-	823	-	721	-	701.48	-
$(NH_4)_2SO_4$	117.39	22.40	58.69	13.26	19.56	5.04	11.74	3.11
$MgSO_4$	8.21	1.57	4.11	0.93	1.37	0.36	0.82	0.22
$FeCl_3$	4.82	0.92	2.41	0.54	0.80	0.21	0.48	0.13
K_2HPO_4	23.33	4.45	11.66	2.64	3.89	1.00	2.33	0.62
$CaCl_2$	4.59	0.88	2.30	0.52	0.77	0.20	0.46	0.12
Seeding Material	15.72	3.00	13.27	3.00	11.64	3.00	11.31	3.00
NH_4CL	-	-	-	-	-	-	-	-
Total	1498.82	100	1265.44	100	1109.03	100	1078.62	100

APPENDIX B

CONSOLIDATION DATA

TABLE B-1.--Consolidation Data, Clay Kaolinite.

Beaker	100 CLAY
Date	6-10-77
X_{FI} (%)	0
X_{CI} (%)	100
X_{FO} (%)	0
X_{CA} (%)	100
G_{SI}	2.70
W_L (gm)	0
W_{tl} (gm)	1383
W_t-W_L(gm)	1838
X_{DI} (%)	0
W_{FI} (gm)	0
W_{CI} (gm)	1383
W_{SI} (gm)	1383
H_{SI} (cm)	2.98
PRESS	0-5.81
H_i (IN)	--
H_f (IN)	3.00
e	1.56
X_{WE} (%)	58
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.00
H_f (IN)	2.75
e	1.35
X_{WE}	50
TIME (MIN)	DIAL READING (10^{-3} IN)
0.5	8
0.7	8.2
2	9.0
4	10.6
8	13.1
16	17.9
31	23.8
60	34.7
90	44.3
120	54.4
154	61.1
400	95.0
780	110.8
850	111.4
900	112.0
1482	118.8
PRESS	11.6-23.3gm/cm^2
H_i(IN)	2.75
H_f(IN)	2.50
e	1.13
X_{WE}(%)	42
TIME (MIN.)	DIAL READING (10^{-3} IN)
0.25	12
1	13.6
2	15
4	17.2
8	21.3
16	27.3
30	35.8
72	54.4
150	74.3
240	88.4
366	100
620	110.9
1350	116.4
PRESS	23.3-34.9gm/cm^2
H_i(IN)	2.50
H_f(IN)	2.32
e	0.98
X_{WE}(%)	36
TIME (MIN)	DIAL READING (10^{-3} IN)
0.25	43.8
1	44.9
2	45.9
4	47.2
9	49.3
16	51.7
34	54.7
75	59.5
105	61.8
109	66
300	69
450	71.5
520	72
620	72.7
1163	74.6

TABLE B-2 Consolidation Data, Anaerobic, Stage I.

Beaker	A
Date	12-15-77
X_{FI} (%)	33.22
X_{CI} (%)	66.79
X_{FO} (%)	33.22
X_{CO} (%)	66.79
G_{SI}	2.16
W_L (gm)	0.
W_{tl} (gm)	500.
W_t-W_L(gm)	500.
X_{DI} (%)	0.
W_{FI} (gm)	166.10
W_{CI} (gm)	333.90
W_{SI} (gm)	500.
H_{SI} (cm)	1.35

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.75
e	7.94
X_{WE} (%)	369

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.35
e	7.18
X_{WE} (%)	334

TIME (MIN)	DIAL READING (10^{-3} IN)
	215
0.25	255.
0.50	272.
0.75	289.
1.	300.
2.	340.
4.	397.
8.	466.
16.	550.
30.	618.
64.	678.

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.35
H_f (IN)	3.94
e	6.41
X_{WE}(%)	298

TIME (MIN)	DIAL READING (10^{-3}IN)
0	172
0.10	200
0.25	218
0.50	238
0.75	256
1.	270
2.	318
4.	378
8.	446
16	508
30	552
60	583

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.94
H_f (IN)	3.73
e	6.02

X_{WE}(%)	279
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	82.
0.25	100.
0.50	109.
0.75	117.
1.	122.
2.	140.
4.	164.
8.	193.
16.	222.
30.	246.
60.	268.
100.	284.

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 1)

Beaker	B
Date	12-16-77
X_{FI} (%)	29.64
X_{CI} (%)	70.37
X_{FO} (%)	29.64
X_{CO} (%)	70.37
G_{SI}	2.21
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	148.20
W_{CI} (gm)	351.80
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.90
e	8.43
X_{WE} (%)	383

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.90
H_f (IN)	4.47
e	7.60
X_{WE} (%)	345

TIME (MIN)	DIAL READING (10^{-3} IN)
0	120
0.10	145
0.25	158
0.5	174
0.75	188
1	199
2	233
4	282
8	347
16	420
30	484
60	549

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.47
H_f (IN)	4.04
e	6.77
X_{WE}(%)	308

TIME (MIN)	DIAL READING (10^{-3} IN)
0	190
0.1	227
0.25	246
0.50	266
1.0	295
2	332
4	391
8	458
16	524
40	604
60	626

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.04
H_f (IN)	3.85
e	6.40
X_{WE}(%)	291

TIME (MIN)	DIAL READING (10^{-3} IN)
0	70
0.1	83
0.25	88
0.5	95
0.75	101
1.0	105
2	120
5	151
8	172
16	205
30	234
64	266
100	287

B-2 Consolidation Data, Anaerobic, Stage I. (Continue 2)

Beaker	C
Date	12-17-77
X_{FI} (%)	31.60
X_{CI} (%)	68.36
X_{FO} (%)	31.60
X_{CO} (%)	68.36
G_{SI}	2.18
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	158
W_{CI} (gm)	342
W_{SI} (gm)	500
H_{SI} (cm)	1.33

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.00
e	8.52
X_{WE} (%)	391

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.00
H_f (IN)	4.36
e	7.30
X_{WE} (%)	335

TIME (MIN)	DIAL READING (10^{-3} IN)
0	118
0.1	156
0.25	185
0.50	216
0.75	242
1.0	265
2	334
4	422
8	522
16	622
34	708
60	760

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.36
H_f (IN)	3.88
e	6.39
X_{WE}(%)	293

TIME (MIN)	DIAL READING (10^{-3} IN)
0.0	6
0.1	48
0.25	71
0.5	102
0.75	128
1.0	145
2	203
4	274
8	346
16	406
30	446
60	487

PRESS	23.3-34.9gm/cm^2
H_i (IN)	3.88
H_f (IN)	3.69
e	6.03

X_{WF}(%)	277
TIME (MIN)	DIAL READING (10^{-3} IN)
0	163
0.1	176
0.25	186
0.50	198
0.75	206
1.00	212
2	235
4	260
8	285
16	307
30	324
60	343
120	362

B-2 Consolidation Data, Anaerobic, Stage I. (Continue 3)

Beaker	D
Date	12-18-77
X_{FI} (%)	32.03
X_{CI} (%)	67.98
X_{FO} (%)	32.03
X_{CO} (%)	67.98
G_{SI}	2.18
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	160.15
W_{CI} (gm)	339.85
W_{SI} (gm)	500
H_{SI} (cm)	1.33

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.80
e	8.17
X_{WE} (%)	3.74

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.80
H_f (IN)	4.44
e	7.48
X_{WE} (%)	3.42

TIME (MIN)	DIAL READING (10^{-3} IN)
0	182
0.1	199
0.25	211
0.50	225
0.75	238
1.0	247
2	277
4	317
8	373
16	438
30	495
60	543

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.44
H_f (IN)	3.98
e	6.60
X_{WE}(%)	3.02

TIME (MIN)	DIAL READING (10^3 IN)
0	113
.10	132
0.25	147
0.50	165
0.75	179
1.0	192
2	230
4	284
8	358
20	474
30	521
60	585

PRESS	23.3-34.9gm/cm^2
H_i (IN)	3.98
H_f (IN)	3.77
e	6.20

X_{WE}(%)	2.84
TIME (MIN)	DIAL READING (10^{-3} IN)
0	83
.1	92
0.25	99
0.50	107
0.75	114
1.0	120
2	138
4	162
8	191
16	221
30	244
60	267
100	282

B-2 Consolidation Data, Anaerobic, Stage I. (Continue 4)

Beaker	E
Date	12-19-77
X_{FI} (%)	30.91
X_{CI} (%)	69.09
X_{FO} (%)	30.91
X_{CO} (%)	69.09
G_{SI}	2.19
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	154.55
W_{CI} (gm)	345.45
W_{SI} (gm)	500
H_{SI} (cm)	1.33

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.78
e	8.13
X_{WE} (%)	372

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.78
H_f (IN)	4.29
e	7.19
X_{WE} (%)	329

TIME (MIN)	DIAL READING (10^{-3} IN)
0	295
0.10	324
0.25	347
0.50	372
0.75	394
1.0	411
2	467
4	537
9	626
16	684
30	730
60	783

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.29
H_f (IN)	3.87
e	6.39
X_{WE}(%)	292

TIME (MIN)	DIAL READING (10^{-3} IN)
0	146
0.10	178
0.25	200
0.50	228
0.75	250
1.0	267
2	318
4	381
8	447
16	503
30.5	543
60	572

PRESS	23.3-34.9gm/cm^2
H_i (IN)	3.87
H_f (IN)	3.62
e	5.91

X_{WE}(%)	271
TIME (MIN)	DIAL READING (10^{-3} IN)
0	211
0.10	218
0.25	231
0.50	242
0.75	252
1.0	258
2	284
4	315
8	352
16	386
30	412
60	437
100	456

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 5)

Beaker	F
Date	12-20-77
X_{FI} (%)	30.00
X_{CI} (%)	70.00
X_{FO} (%)	30.00
X_{CO} (%)	70.00
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L (gm)	500
X_{DI} (%)	0
W_{FI} (gm)	150
W_{CI} (gm)	350
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.63
e	7.84
X_{WE} (%)	359

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.63
H_f (IN)	4.27
e	7.15
X_{WE} (%)	327

TIME (MIN)	DIAL READING (10^{-3} IN)
0	179
0.10	204
0.25	220
0.50	240
0.75	256
1.0	268
2	309
4	362
8	420
16	471
30	509
60	544

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.27
H_f (IN)	3.76
e	6.18
X_{WE} (%)	283

TIME (MIN)	DIAL READING (10^{-3} IN)
0	182
0.10	217
0.25	241
0.50	271
0.75	293
1.0	311
2	368
4	435
8	518
16	596
30	647
60	689

PRESS	23.3-34.9gm/cm^2
H_i (IN)	3.76
H_f (IN)	3.52
e	5.72
X_{WE} (%)	262

TIME (MIN)	DIAL READING (10^{-3} IN)
0	233
0.10	247
0.25	258
0.50	272
0.75	283
1.5	305
2	317
4	350
8	382
16	412
30	434
60	458
100	474

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 6)

Beaker	G
Date	12-21-77
X_{FI} (%)	59.87
X_{CI} (%)	40.13
X_{FO} (%)	59.87
X_{CO} (%)	40.13
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	187.09
W_{CI} (gm)	125.41
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.21
e	12.50
X_{WE} (%)	674

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.21
H_f (IN)	4.88
e	11.65
X_{WE} (%)	628

TIME (MIN)	DIAL READING (10^{-3} IN)
0	110
0.1	144
0.25	168
0.5	192
0.75	214
1.0	230
2	279
4	332
8	379
16	415
30	442
60	471

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.88
H_f (IN)	4.36
e	10.30
X_{WE}(%)	556

TIME (MIN)	DIAL READING (10^{-3} IN)
0	107
0.1	143
0.25	175
0.50	214
0.75	243
1.0	267
2	337
4	416
8	490
16	545
30	584
60	620
68	627

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.36
H_f (IN)	4.06
e	9.52
X_{WE}(%)	514

TIME (MIN)	DIAL READING (10^{-3} IN)
0	27
0.10	50
0.25	65
0.50	84
0.75	99
1.0	111
2	147
4	185
8	223
16	255
30	282
60	309
100	327

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 7)

Beaker	H
Date	12-22-77
X_{FI} (%)	59.49
X_{CI} (%)	40.51
X_{FO} (%)	59.49
X_{CO} (%)	40.51
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	185.91
W_{CI} (gm)	126.59
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.42
e	13.05
X_{WE} (%)	440
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.42
H_f (IN)	5.05
e	12.09
X_{WE} (%)	652
TIME (MIN)	DIAL READING (10^{-3} IN)
0	230
0.1	278
0.25	307
0.50	340
0.75	365
1.0	383
2	433
4	480
8	522
16	560
30	588
45	605
60	616
PRESS	11.6-23.3gm/cm^2
H_i (IN)	5.05
H_f (IN)	4.51
e	10.69
X_{WE}(%)	577
TIME (MIN)	DIAL READING (10^{-3} (IN)
0	118
0.10	200
0.25	247
0.50	300
0.75	337
1.0	366
2	438
4	504
8	555
16	599
30	633
45	654
60	668
PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.51
H_f (IN)	4.20
e	9.89
X_{WE}(%)	533
TIME (MIN)	DIAL READING (10^{-3} IN)
0	236
0.10	265
0.25	285
0.50	310
0.75	330
1.0	345
2	385
4	426
8	464
16	497
32	524
45	538
60	549
100	570
150	585

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 8)

Beaker	I
Date	12-23-77
X_{FI} (%)	60.28
X_{CI} (%)	39.72
X_{FO} (%)	60.28
X_{CO} (%)	39.72
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	188.38
W_{CI} (gm)	124.13
W_{SI} (gm)	312.5
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	
H_f (IN)	5.13
e	12.30
X_{WE} (%)	663

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.13
H_f (IN)	4.87
e	11.62
X_{WE} (%)	627

TIME (MIN)	DIAL READING (10^{-3} IN)
0	95
0.10	126
0.25	152
0.50	178
0.75	197
1.0	212
2	250
4	282
8	307
16	328
30	346
45	358
60	367

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.87
H_f (IN)	4.42
e	10.46
X_{WE}(%)	564

TIME (MIN)	DIAL READING (10^{-3} IN)
0	147
0.10	200
0.25	237
0.50	285
0.75	318
1.0	344
2	407
4	463
8	505
16	539
30	568
60	597

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.42
H_f (IN)	4.12
e	9.68
X_{WE}(%)	522

TIME (MIN)	DIAL READING (10^{-3} IN)
0	185
0.10	---
0.25	247
0.50	273
0.75	290
1.0	305
2	338
4	368
8	393
16	418
30	438
60	465
100	485

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 9)

Beaker	J
Date	12-24-77
X_{FI} (%)	60.85
X_{CI} (%)	39.15
X_{FO} (%)	60.85
X_{CO} (%)	39.15
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312
W_t-W_L(gm)	312
X_{DI} (%)	0
W_{FI} (gm)	190.16
W_{CI} (gm)	122.34
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.94
e	11.80
X_{WE} (%)	637

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.94
H_f (IN)	4.67
e	11.10
X_{WE} (%)	599

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.10	259
0.25	290
0.50	320
0.75	336
1.0	353
2	382
4	405
8	424
16	443
32	460
60	475

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.67
H_f (IN)	4.23
e	9.96
X_{WE}(%)	537

TIME (MIN)	DIAL READING (10^{-3} IN)
0	140
0.10	220
0.25	268
0.50	315
0.75	350
1.0	372
2	426
4	470
8	303
16	531
33	558
45	570
60	580

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.23
H_f (IN)	3.95
e	9.24
X_{WE}(%)	498

TIME (MIN)	DIAL READING (10^{-3} IN)
0	102
0.10	133
0.25	158
0.50	184
0.75	202
1.0	215
2	248
4	276
8	300
16	321
30	339
60	361
100	378

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 10)

Beaker	K
Date	12-25-77
X_{FI} (%)	61.00
X_{CI} (%)	39.00
X_{FO} (%)	61.00
X_{CO} (%)	39.00
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	190.63
W_{CI} (gm)	121.88
W_{SI} (gm)	312.5
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.81
e	11.47
X_{WE} (%)	619

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.81
H_f (IN)	4.60
e	10.92
X_{WE} (%)	589

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.10	248
0.25	272
0.50	293
0.75	307
1.0	317
2	338
4	354
8	368
16	381
30	393
64	409

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.60
H_f (IN)	4.32
e	10.20
X_{WE}(%)	550

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.1	245
0.25	266
0.50	293
0.75	312
1.0	327
2	375
4	395
8	421
16	443
30	463
60	485

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.32
H_f (IN)	4.03
e	9.45

X_{WE}(%)	510

TIME (MIN)	DIAL READING (10^{-3} (IN)
0	90
0.10	113
0.25	134
0.50	157
0.75	174
1.0	188
2	222
4	255
8	284
16	309
30	337
60	355
100	372

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 11)

Beaker	L
Date	12-26-77
X_{FI} (%)	60.90
X_{CI} (%)	39.10
X_{FO} (%)	60.90
X_{CO} (%)	39.10
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	190.31
W_{CI} (gm)	122.19
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.75
e	11.31
X_{WE} (%)	610

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.55
e	10.79
X_{WE} (%)	582

TIME (MIN)	DIAL READING (10^{-3} IN)
0	90
0.10	132
0.25	151
0.50	171
0.75	183
1.0	192
2	212
4	229
8	245
16	260
30	274
60	292

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.55
H_f (IN)	4.13
e	9.70
X_{WE}(%)	523

TIME (MIN)	DIAL READING (10^{-3} IN)
0	215
0 .10	280
0.25	316
0.50	360
0.75	390
1.0	414
2	471
4	518
8	554
16	581
30	605
60	632

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.13
H_f (IN)	3.87
e	9.03

X_{WE}(%)	487
TIME (MIN)	DIAL READING (10^{-3} IN)
0	311
0.10	352
0.25	375
0.50	400
0.75	416
1.00	429
2	459
4	486
8	509
16	531
30	551
60	574
100	591

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 12)

Beaker	M
Date	12-27-77
X_{FI} (%)	79.05
X_{CI} (%)	20.95
X_{FO} (%)	79.05
X_{CO} (%)	20.95
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	177.85
W_{CI} (gm)	47.14
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.41
e	16.85
X_{WE} (%)	992

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.41
H_f (IN)	4.98
e	15.43
X_{WE} (%)	908

TIME (MIN)	DIAL READING (10^{-3} IN)
0	255
0.10	315
0.25	357
0.50	400
0.75	432
1.00	456
2	511
4	556
8	599
16	630
30	655
45	685
60	672

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.98
H_f (IN)	4.41
e	13.55
X_{WE}(%)	797

TIME (MIN)	DIAL READING (10^{-3} IN)
0	240
0.10	323
0.25	378
0.50	443
0.75	487
1.0	517
2	591
4	647
8	697
16	745
32	779
45	808
60	795

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.41
H_f (IN)	4.04
e	12.33
X_{WE}(%)	726

TIME (MIN)	DIAL READING (10^{-3} IN)
0	282
0.1	336
0.25	361
0.50	397
0.75	423
1.0	442
2	490
4	537
8	570
16	598
30	622
45	650
60	639
100	671

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 13)

Beaker	N
Date	12-28-77
X_{FI} (%)	79.97
X_{CI} (%)	20.03
X_{FO} (%)	79.97
X_{CO} (%)	20.03
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	179.93
W_{CI} (gm)	45.07
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.63
e	17.57
X_{WE} (%)	1034

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.63
H_f (IN)	5.16
e	16.02
X_{WE} (%)	943

TIME (MIN)	DIAL READING (10^{-3} IN)
0	178
0.10	244
0.25	292
0.50	339
0.75	371
1.0	396
2	462
4	515
8	555
16	590
30	618
45	647
60	637

PRESS	11.6-23.3gm/cm^2
H_i (IN)	5.16
H_f (IN)	4.62
e	14.24
X_{WE}(%)	838

TIME (MIN)	DIAL READING (10^{-3})
0	220
0.10	297
0.25	338
0.50	397
0.75	439
1.0	470
2	545
4	609
8	658
17	700
30	730
45	765
60	750

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.62
H_f (IN)	4.25
e	13.12
X_{WE}(%)	772

TIME (MIN)	DIAL READING (10^{-3} IN)
0	65
0.10	103
0.25	130
0.50	160
0.75	181
1.00	198
2	237
4	277
8	311
16	343
30	370
60	401
100	423

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 14)

Beaker	0
Date	12-24-77
X_{FI} (%)	80.03
X_{CI} (%)	19.97
X_{FO} (%)	80.03
X_{CO} (%)	19.97
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.07
W_{CI} (gm)	44.93
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.08
e	15.76
X_{WE} (%)	928

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.08
H_f (IN)	4.79
e	14.80
X_{WE} (%)	871

TIME (MIN)	DIAL READING (10^{-3} IN)
0	227
0.10	288
0.25	327
0.50	362
0.75	382
1.0	396
2	430
4	444
8	462
16	480
30	496
60	516

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.79
H_f (IN)	4.37
e	13.42
X_{WE}(%)	790

TIME (MIN)	DIAL READING (10^{-3} IN)
0	10
0.10	92
0.25	149
0.50	200
0.75	233
1.00	256
2	302
4	338
8	363
16	386
30	407
60	431

PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.37
H_f (IN)	4.11
e	12.56

X_{WE}(%)	739

TIME (MIN)	DIAL READING (10^{-3} IN)
0	360
0.10	405
0.25	431
0.50	465
0.75	483
1.0	495
2	520
4	543
8	562
16	580
30	598
60	617
100	628

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 15)

Beaker	P
Date	12-30-77
X_{FI} (%)	80.40
X_{CI} (%)	19.60
X_{FO} (%)	80.40
X_{CO} (%)	19.60
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L (gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.90
W_{CI} (gm)	44.10
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.00
e	15.49
X_{WE} (%)	912

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.00
H_f (IN)	4.73
e	14.60
X_{WE} (%)	860

TIME (MIN)	DIAL READING (10^{-3} IN)
0	133
0.10	185
0.25	218
0.50	250
0.75	270
1.00	284
2	313
4	334
9	355
16	368
34	386
60	400

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.73
H_f (IN)	4.27
e	13.09
X_{WE} (%)	770

TIME (MIN)	DIAL READING (10^{-3} IN)
0	225
0.10	305
0.25	358
0.50	415
0.75	452
1.0	480
2	540
4	584
9	620
16	642
30	666
60	691

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.27
H_f (IN)	3.96
e	12.06

X_{WE} (%)	710
TIME (MIN)	DIAL READING (10^{-3} IN)
0	20
0.10	59
0.25	86
0.50	118
0.75	140
1.0	157
2	194
5	236
8	254
16	273
30	295
60	323
100	341

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 16)

Beaker	Q
Date	12-31-77
X_{FI} (%)	80.07
X_{CI} (%)	19.93
X_{FO} (%)	80.07
X_{CO} (%)	19.93
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.16
W_{CI} (gm)	44.84
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.06
e	15.69
X_{WE} (%)	924

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.06
H_f (IN)	4.72
e	14.57
X_{WE} (%)	858

TIME (MIN)	DIAL READING (10^{-3} IN)
0	184
0.10	258
0.25	303
0.50	348
0.75	373
1.0	389
2	424
4	446
8	465
16	485
30	504
60	526

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.72
H_f (IN)	4.24
e	12.99
X_{WE} (%)	764

TIME (MIN)	DIAL READING (10^{-3} IN)
0	185
0.1	282
0.25	343
0.5	407
0.75	444
1.0	472
2	523
4	558
8	590
16	614
30	637
60	663

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.24
H_f (IN)	3.95
e	12.03

X_{WE}(%)	708

TIME (MIN)	DIAL READING (10^{-3} IN)
0	125
0.1	168
0.25	198
0.50	230
0.75	250
1.0	265
2	299
4	328
8	352
16	374
30	393
60	415
100	433

TABLE B-2 Consolidation Data, Anaerobic, Stage I . (Continue 17)

Beaker	R
Date	1-1-78
X_{FI} (%)	80.10
X_{CI} (%)	19.90
X_{FO} (%)	80.10
X_{CO} (%)	19.90
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.33
W_{CI} (gm)	44.78
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.81
e	14.87
X_{WE} (%)	875

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.81
H_f (IN)	4.47
e	13.75
X_{WE} (%)	809

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.10	282
0.25	330
0.50	371
0.75	395
1.0	410
2	442
4	460
8	482
16	500
30	516
60	536

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.47
H_f (IN)	4.14
e	12.66
X_{WE}(%)	745

TIME (MIN)	DIAL READING (10^{-3} IN)
0	270
0.10	330
0.25	370
0.50	409
0.75	435
1.0	454
2	491
4	520
8	545
16	567
30	586
60	608

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.14
H_f (IN)	3.84
e	11.67

X_{WE}(%)	687

TIME (MIN)	DIAL READING (10^{-3} IN)
0	138
0.10	195
0.25	225
0.50	255
0.75	276
1.0	290
2	321
4	348
8	371
16	392
30	411
70	438
108	453

TABLE B-2 Consoldiation Data, Anaerobic, Stage I. (Continue 18)

Beaker	13
Date	1-14-78
X_{FI} (%)	29.69
X_{CI} (%)	70.31
X_{FO} (%)	29.69
X_{CO} (%)	70.31
G_{SI}	2.21
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	351.55
W_{CI} (gm)	148.45
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.63
e	7.84
X_{WE} (%)	359

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.63
H_f (IN)	4.21
e	7.04
X_{WE} (%)	322

TIME (MIN)	DIAL READING (10^{-3} IN)
0	480
0.10	540
0.25	576
0.50	612
0.75	640
1.0	659
2	713
4	760
8	803
16	839
30	869
60	900

PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.21
H_f(IN)	3.71
e	6.09
X_{WE}(%)	278

TIME (MIN)	DIAL READING (10^{-3} IN)
0	305
0.10	362
0.25	403
0.50	452
0.75	488
1.0	515
2	588
4	658
8	715
17	760
30	787
60	871.5

PRESS.	23.3-34.9gm/cm^2
H_i(IN)	3.71
H_f(IN)	3.35
e	5.40

X_{WE}(%)	247
TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.10	229
0.25	252
0.50	279
0.75	299
1.0	316
2	362
4	415
8	464
16	502
30	532
45	549
60	561.5
100	585

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 19)

Beaker	14
Date	1-15-78
X_{FI} (%)	30.65
X_{CI} (%)	69.35
X_{FO} (%)	30.65
X_{CO} (%)	69.35
G_{SI}	2.19
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	153.25
W_{CI} (gm)	346.75
W_{SI} (gm)	500
H_{SI} (cm)	1.33

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.81
e	8.19
X_{WE} (%)	375

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.81
H_f (IN)	4.54
e	7.67
X_{WE} (%)	351

TIME (MIN)	DIAL READING (10^{-3} IN)
0	440
0.10	474
0.25	494
0.50	516
0.75	533
1.0	548
2	587
4	627
8	660
16	682
30	698
60	714

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.54
H_f (IN)	3.95
e	6.54
X_{WE}(%)	299

TIME (MIN)	DIAL READING (10^{-3} IN)
0	240
0.10	298
0.25	339
0.50	384
0.75	416
1.0	443
2	523
4	600
8	692
16	754
30	791
60	822

PRESS.	23.3-24.9gm/cm^2
H_i (IN)	3.95
H_f (IN)	3.57
e	5.82

X_{WE}(%)	266
TIME (MIN)	DIAL READING (10^{-3} IN)
0	154
0.10	184
0.25	203
0.50	228
0.75	248
1.0	265
2	313
4	373
8	435
16	468
30	506
45	523
60	536
100	558

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 20)

Beaker	15
Date	1-16-78
X_{FI} (%)	61.54
X_{CI} (%)	38.46
X_{FO} (%)	61.54
X_{CO} (%)	38.46
G_{SI}	1.84
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	192.31
W_{CI} (gm)	120.19
W_{SI} (gm)	312.5
H_{SI} (cm)	0.99

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.75
e	11.31
X_{WE} (%)	610

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.53
e	10.74
X_{WE} (%)	579

TIME (MIN)	DIAL READING (10^{-3} IN)
0	392
0.10	435
0.25	460
0.50	478
0.75	489
1.0	495
2	507
4	518
8	528
16	538
30	548
45	555
60	561
	611

PRESS.	6.11-23.3gm/cm^2
H_i (IN)	4.53
H_f (IN)	4.24
e	9.99
X_{WE} (%)	539

TIME (MIN)	DIAL READING (10^{-3} IN)
0	232
0.10	337
0.25	385
0.50	442
0.75	441
1.0	451
2	470
4	483
8	495
16	506
30	515
64	528

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.24
H_f (IN)	3.91
e	9.13
X_{WE} (%)	493

TIME (MIN)	DIAL READING (10^{-3} IN)
0	528
0.10	588
0.25	630
0.50	674
0.75	698
1.0	714
2	748
4	774
16	812
30	831
60	861
100	883

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 21)

Beaker	16
Date	1-17-78
X_{FI} (%)	60.06
X_{CI} (%)	39.94
X_{FO} (%)	60.06
X_{CO} (%)	39.94
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L (gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	187.69
W_{CI} (gm)	124.81
W_{SI} (gm)	312.5
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.53
e	10.74
X_{WE} (%)	579

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.53
H_f (IN)	4.35
e	10.27
X_{WE} (%)	554

TIME (MIN)	DIAL READING (10^{-3} IN)
0	415
0.10	472
0.25	493
0.50	511
0.75	520
1.0	525
2	537
4	547
8	557
16	567
30	578
60	591

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.35
H_f (IN)	4.00
e	9.37
X_{WE} (%)	505

TIME (MIN)	DIAL READING (10^{-3} IN)
0	323
0.10	450
0.25	495
0.50	533
0.75	553
1.0	564
2	598
4	604
8	621
16	639
30	656
60	681

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.00
H_f (IN)	3.68
e	8.54

X_{WE} (%)	461
TIME (MIN)	DIAL READING (10^{-3} IN)
0	248
0.10	320
0.25	359
0.50	393
0.75	413
1.0	428
2	458
4	482
8	504
16	526
30	546
45	562
60	572

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 22)

Beaker	17
Date	1-18-78
X_{FI} (%)	80.27
X_{CI} (%)	19.73
X_{FO} (%)	80.27
X_{CO} (%)	19.73
G_{SI}	1.68
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.61
W_{CI} (gm)	44.39
W_{SI} (gm)	225
H_{SI} (cm)	0.78

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.69
e	14.27
X_{WE} (%)	851

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.69
H_f (IN)	4.43
e	13.43
X_{WE} (%)	801

TIME (MIN)	DIAL READING (10^{-3} IN)
0	486
0.25	637
0.50	659
0.75	671
1.00	677
2	690
4	700
8	712
16	723
30	734
45	742
60	748

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.43
H_f (IN)	4.11
e	12.38
X_{WE}(%)	738

TIME (MIN)	DIAL READING (10^{-3} IN)
0	422
0.1	505
0.25	562
0.50	600
0.75	---
1	627
2	650
4	669
8	686
16	704
30	718
60	737

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.11
H_f (IN)	3.85
e	11.54
X_{WE}(%)	688

TIME (MIN)	DIAL READING (10^{-3} IN)
0	122
0.10	186
0.25	222
0.50	249
0.75	264
1.00	273
2	292
4	311
9	331
16	347
30	365
60	387
100	404

TABLE B-2 Consolidation Data, Anaerobic, Stage I. (Continue 23)

Beaker	18
Date	1-19-78
X_{FI} (%)	80.04
X_{CI} (%)	19.96
X_{FO} (%)	80.04
X_{CO} (%)	19.96
G_{SI}	1.68
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.09
W_{CI} (gm)	44.91
W_{SI} (gm)	225
H_{SI} (cm)	0.78
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.44
e	13.46
X_{WE} (%)	802

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.44
H_f (IN)	4.35
e	13.17
X_{WE} (%)	785

TIME (MIN)	DIAL READING (10^{-3} IN)
0	4-8
0.10	534
0.25	545
0.75	554
1.0	556
2	560
4	564
8	568
16	572.5
30	576
60	581
81	584

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.35
H_f (IN)	4.03
e	12.12
X_{WE}(%)	723

TIME (MIN)	DIAL READING (10^{-3} IN)
0	64
0.10	170
0.25	222
0.5	260
0.75	277
1.0	287
2	306
4	323
8	337.5
16	353
30	368
45	378
60	387

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.03
H_f (IN)	3.72

e	11.11
X_{WE}(%)	663

TIME (MIN)	DIAL READING (10^{-3} IN)
0.10	466
0.25	512
0.50	547
0.75	564
1.0	574
2	597
4	617
8	632
16	654
30	674
45	686.5
60	696
120	719

TABLE B-3 Consolidation Data, Aerobic, Stage I

Beaker	1
Date	1-2-78
X_{FI} (%)	30.40
X_{CI} (%)	69.60
X_{FO} (%)	30.40
X_{CO} (%)	69.60
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	152
W_{CI} (gm)	348
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.88
e	8.32
X_{WE} (%)	381

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.88
H_f (IN)	4.80
e	8.17
X_{WE} (%)	374

TIME (MIN)	DIAL READING (10^{-3} IN)
0	144
0.10	168
0.25	174
0.50	180
0.75	184
1.0	187
2	194
4	201
8	206.2
16	212.1
30	217
60	222

PRESS.	11.6-23.3gm/cm^3
H_i (IN)	4.80
H_f (IN)	4.61
e	7.80
X_{WE}(%)	357

TIME (MIN)	DIAL READING (10^{-3} IN)
0	430
0.10	452
0.25	465
0.50	480
0.75	488
1.0	496
2	517
4	541
8	566
16	586
30	603
60	621

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.61
H_f (IN)	4.44
e	7.48

X_{WE}(%)	342

TIME (MIN)	DIAL READING (10^{-3} IN)
0	280
0.1	296
0.25	303
0.50	312
0.75	318
1.0	323
2	339
4	360
8	383
16	408
30	428
60	449
100	463

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 1)

Beaker	2
Date	1-3-78
X_{FI} (%)	30.30
X_{CI} (%)	69.71
X_{FO} (%)	30.30
X_{CO} (%)	69.71
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	151.50
W_{CI} (gm)	348.50
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.75
e	8.07
X_{WE} (%)	369

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.65
e	7.89
X_{WE} (%)	361

TIME (MIN)	DIAL READING (10^{-3} IN)
0	270
0.10	312
0.25	---
0.50	323
0.75	327
1.0	329
2	335
4	342
8	349
16	358
30	366
60	375

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.65
H_f (IN)	4.49
e	7.57
X_{WE} (%)	347

TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
0.10	370
0.25	---
0.50	396
0.75	403
1.0	407
2	416
4	424
8	430
16	438
30	445
45	450
60	453

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.49
H_f (IN)	4.31

e	7.23
X_{WE} (%)	331

TIME (MIN)	DIAL READING (10^{-3} IN)
0	452
0.10	490
0.25	505
0.50	520
0.75	531
1.0	538
2	555
4	570
8	585
16	601
30	616
60	631
100	642

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 2)

Beaker	3
Date	1-4-78
X_{FI} (%)	30.18
X_{CI} (%)	69.82
X_{FO} (%)	30.18
X_{CO} (%)	69.82
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	0
W_{FI} (gm)	150.90
W_{CI} (gm)	349.10
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.31
e	7.23
X_{WE} (%)	331

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.31
H_f (IN)	4.27
e	7.15
X_{WE} (%)	327

TIME (MIN)	DIAL READING (10^{-3} IN)
0	470
0.10	478
0.25	482
0.50	485
0.75	487
1.0	489
2	492
4	496
8	499
16	502
30	505
60	509

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.27
H_f (IN)	4.19
e	7.00
X_{WE}(%)	320

TIME (MIN)	DIAL READING (10^{-3} IN)
0	160
0.10	186
0.25	192
0.50	198
0.75	202
1.00	205
2	213
4	221
8	227
16	233.5
30	238.5
60	245

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.19
H_f (IN)	4.08
e	6.79

X_{WE}(%)	311
TIME (MIN)	DIAL READING (10^{-3} IN)
0	83
0.10	98
0.25	105
0.50	112
0.75	117
1.0	121
2	132
4	145
8	157
16	168.5
30	177
60	188
76	192
100	196

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 3)

Beaker	4
Date	1-5-78
X_{FI} (%)	29.85
X_{CI} (%)	70.16
X_{FO} (%)	29.85
X_{CO} (%)	70.16
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L (gm)	500
X_{DI} (%)	0
W_{FI} (gm)	149.25
W_{CI} (gm)	350.75
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.31
e	7.23
X_{WE} (%)	331

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.31
H_f (IN)	4.25
e	7.12
X_{WE} (%)	326

TIME (MIN)	DIAL READING (10^{-3} IN)
0	315
0.10	346
0.25	349
0.50	351.5
0.75	353.5
1.0	355
2	358
4	361.5
8	366
21	370
30	372
60	375

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.25
H_f (IN)	4.14
e	6.91
X_{WE} (%)	316

TIME (MIN)	DIAL READING (10^{-3} IN)
0	345
0.10	375
0.25	384
0.50	392.5
0.75	398
1.0	403
2	413
4	403
8	430
16	437
30	444
60	452

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.14
H_f (IN)	4.01
e	6.66

X_{WE} (%)	305
TIME (MIN)	DIAL READING (10^{-3} IN)
0	452
0.10	470
0.25	480
0.50	490
0.75	498
1.0	504
2	520
4	536
8	551
16	564.5
30	576
60	588
100	604

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 4)

Beaker	5
Date	1-6-78
X_{FI} (%)	59.96
X_{CI} (%)	40.04
X_{FO} (%)	59.96
X_{CO} (%)	40.04
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	187.38
W_{CI} (gm)	125.13
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.13
e	12.30
X_{WE} (%)	663

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.13
H_f (IN)	5.06
e	12.11
X_{WE} (%)	653

TIME (MIN)	DIAL READING (10^{-3} IN)
0	294
0.10	314
0.25	327
0.50	330
0.75	332
1.00	333
2	337
4	341.5
8	346.5
16	353
30	360
60	369

PRESS.	11-6-23.3gm/cm^2
H_i (IN)	5.06
H_f (IN)	4.88
e	11.65
X_{WE} (%)	628

TIME (MIN)	DIAL READING (10^{-3} IN)
0	264
0.10	317
0.25	324
0.50	328
0.75	332
1.0	334
2	340
4	386
8	400
16	412
30	425
60	442

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.88
H_f (IN)	4.70
e	11.18
X_{WE} (%)	603

TIME (MIN)	DIAL READING (10^{-3} IN)
0	014
0.10	86
0.25	98
0.5	107
0.75	---
1.0	117
2	128
4	140
8	153
16	168
30	182
45	193
60	201
100	215

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 5)

Beaker	6
Date	1-7-78
X_{FI} (%)	60.73
X_{CI} (%)	39.27
X_{FO} (%)	60.73
X_{CO} (%)	39.27
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	189.78
W_{CI} (gm)	122.72
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.23
e	12.56
X_{WE} (%)	677

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.23
H_f (IN)	5.13
e	12.30
X_{WE} (%)	663

TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
0.10	347
0.25	352
0.50	356
0.75	359
1.00	361
2	366
4	372
8	378
16	385
30	392
45	397
60	401

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	5.13
H_f (IN)	4.96
e	11.86
X_{WE} (%)	639

TIME (MIN)	DIAL READING (10^{-3} IN)
0	172
0.10	251
0.25	264
0.50	271
0.75	276
1.0	279
2	---
4	295
8	304
16	315
30	325
60	338

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.96
H_f (IN)	4.79
e	11.41
X_{WE} (%)	616

TIME (MIN)	DIAL READING (10^{-3} IN)
0	80
0.10	140
0.25	151
0.50	160
0.75	166
1.00	170
2	181
4	192
8	206.5
16	222
30	238
60	257
100	270

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 6)

Beaker	7
Date	1-8-78
X_{FI} (%)	60.56
X_{CI} (%)	39.45
X_{FO} (%)	60.56
X_{CO} (%)	39.45
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	189.25
W_{CI} (gm)	123.25
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.94
e	11.80
X_{WE} (%)	637
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.94
H_f (IN)	4.80
e	11.44
X_{WE} (%)	617
TIME (MIN)	DIAL READING (10^{-3} IN)
0	295
0.10	367
0.25	373
0.50	379
0.75	382.5
1.0	385
2	391.5
4	398
8	405
16	412.5
30	421
45	427
60	431
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.80
H_f (IN)	4.65
e	11.44
X_{WE}(%)	617
TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.10	276
0.25	284
0.50	292
0.75	296
1.0	299
2	307
4	315.5
8	325
18	336.5
30	345
45	357.5
60	352
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.65
H_f (IN)	4.47
e	10.59
X_{WE}(%)	571
TIME (MIN)	DIAL READING (10^{-3} IN)
0	358
0.10	436
0.25	445
0.50	454
0.75	460
1.0	464
2	474
4	484
8	496
16	508.5
30	521
45	537
60	530
100	547

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 7)

Beaker	8
Date	1-9-78
X_{FI} (%)	59.97
X_{CI} (%)	40.03
X_{FO} (%)	59.97
X_{CO} (%)	40.03
G_{SI}	1.86
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	187.41
W_{CI} (gm)	125.09
W_{SI} (gm)	312.50
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.63
e	11.00
X_{WE} (%)	593

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.63
H_f (IN)	4.55
e	10.79
X_{WE} (%)	582

TIME (MIN)	DIAL READING (10^{-3} IN)
0	454
0.10	495
0.25	499
0.50	503
0.75	505
1.0	506.5
2	510.5
4	515
8	520
16	525
30	531.5
60	538.5

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.55
H_f (IN)	4.39
e	10.38
X_{WE}(%)	560

TIME (MIN)	DIAL READING (10^{-3} IN)
0	20
0.10	99
0.25	108
0.50	115
0.75	118.5
1.0	121.5
2.7	132
4	136.5
8	144.5
16	153.5
30	163
45	169
60	173

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.39
H_f (IN)	4.25
e	10.02
X_{WE}(%)	540

TIME (MIN)	DIAL READING (10^{-3} IN)
0	65
0.10	121
0.25	130
0.50	137
0.75	141
1.00	144
2	152
4	161
8	171
16	182
30	193
45	201
60	207
100	217

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 8)

Beaker	9
Date	1-10-78
X_{FI} (%)	80.51
X_{CI} (%)	19.49
X_{FO} (%)	80.51
X_{CO} (%)	19.49
G_{SI}	1.68
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	181.15
W_{CI} (gm)	43.85
W_{SI} (gm)	225
H_{SI} (cm)	0.78

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.19
e	15.90
X_{WE} (%)	948

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.19
H_f (IN)	5.07
e	15.51
X_{WE} (%)	925

TIME (MIN)	DIAL READING (10^{-3} IN)
0	271
0.10	320
0.25	327
0.50	332
0.75	336
1.0	338.5
2	344.5
4	352
8	360
16	370
30	379.5
45	386
60	392

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	5.07
H_f (IN)	4.83
e	14.73
X_{WE}(%)	878

TIME (MIN)	DIAL READING (10^{-3} IN)
0	123
0.10	225
0.25	239
0.50	250
0.75	257
1.0	262
2	275
4	288
8	304
16	321
30	338
45	359
60	350

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.83
H_f (IN)	4.59
e	13.95
X_{WE}(%)	832

TIME (MIN)	DIAL READING (10^{-3} IN)
0	355
0.10	438
0.25	452
0.50	463
0.75	471
1.0	476.5
2	491.5
4	509
8	528
16	550
30	570
45	595
60	584.5
100	612.5

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 9)

Beaker	10
Date	1-11-78
X_{FI} (%)	79.91
X_{CI} (%)	20.09
X_{FO} (%)	79.91
X_{CO} (%)	20.09
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	179.80
W_{CI} (gm)	45.20
W_{SI} (gm)	225
H_{SI} (cm)	0.77
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.09
e	12.32
X_{WE} (%)	735
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.09
H_f (IN)	3.99
e	12.00
X_{WE} (%)	715
TIME (MIN)	DIAL READING (10^{-3} IN)
0	220
0.10	268
0.25	273
0.50	277
0.75	280
1.0	282
2	287
4	292
8	298
16	305
45	316
60	320
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.99
H_f (IN)	3.83
e	11.47
X_{WE} (%)	684
TIME (MIN)	DIAL READING (10^{-3} IN)
0	580
0.10	660
0.25	669
0.50	675.5
0.75	680
1.0	683
2	691
4	700
8	709
16	719
30	729.5
45	735
60	738
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.83
H_f (IN)	3.67
e	10.95
X_{WE} (%)	653
TIME (MIN)	DIAL READING (10^{-3} IN)
0	739
0.10	804
0.25	814
0.50	822
0.75	826
1.0	829
2	844
4	852
8	861
16	876
30	888.5
45	893
60	904
100	914

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 10)

Beaker	11
Date	1-12-78
X_{FI} (%)	80.16
X_{CI} (%)	19.84
X_{FO} (%)	80.16
X_{CO} (%)	19.84
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L (gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.36
W_{CI} (gm)	44.64
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.41
e	13.36
X_{WE} (%)	797

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.41
H_f (IN)	4.32
e	13.07
X_{WE} (%)	779

TIME (MIN)	DIAL READING (10^{-3} IN)
0	465
0.10	504
0.25	508
0.50	512
0.75	514.5
1.0	516
2	521
4	525.5
8	531
16	537
35	544.5
45	547.5
64	551.5

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.32
H_f (IN)	4.17
e	12.58
X_{WE} (%)	750

TIME (MIN)	DIAL READING (10^{-3} IN)
0	400
0.10	482
0.25	491
0.50	498
0.75	502
1.0	505
2	512
4	521
8	529
16	538
34	548
45	556.5
60	552.5

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.17
H_f (IN)	4.05
e	12.19
X_{WE} (%)	727

TIME (MIN)	DIAL READING (10^{-3} IN)
0	570
0.10	617
0.25	625
0.50	631.5
0.75	635.5
1.0	638.5
2	646
4	654
8	663
16	672.3
30	682
45	693
60	688.5
100	701

TABLE B-3 Consolidation Data, Aerobic, Stage I. (Continue 11)

Beaker	12
Date	1-13-78
X_{FI} (%)	80.38
X_{CI} (%)	19.63
X_{FO} (%)	80.38
X_{CO} (%)	19.63
G_{SI}	1.69
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	180.86
W_{CI} (gm)	44.14
W_{SI} (gm)	225
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.90
e	11.70
X_{WE} (%)	698

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.90
H_f (IN)	3.77
e	11.28
X_{WE} (%)	672

TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
0.10	358
0.25	367
0.50	373
0.75	378
1.0	380
2	387
5	397
8	402
16	410
28	418
60	429.5

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.77
H_f (IN)	3.51
e	10.43
X_{WE}(%)	622

TIME (MIN)	DIAL READING (10^{-3} (IN)
0	430
0.10	570
0.25	585
0.50	597
0.75	603
1.0	608
2	621
4	634
8	648
16	662.5
30	677
60	694

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.51
H_f (IN)	3.26
e	9.62

X_{WE}(%)	573

TIME (MIN)	DIAL READING (10^{-3} IN)
0	277
0.10	365
0.25	380
0.50	393
0.75	402
1.0	407
2	423
4	440
8	458
16	477
30	494.5
60	520
100	540

TABLE B-4 Consolidation Data, Anaerobic, Stage II

Beaker	A
Date	2-13-78
X_{FI} (%)	30.83
X_{CI} (%)	69.17
X_{FO} (%)	33.21
X_{CO} (%)	66.79
G_{SI}	2.19
W_L (gm)	18.00
W_{tl} (gm)	500
W_t-W_L(gm)	482
X_{DI} (%)	10.4
W_{FI} (gm)	143.42
W_{CI} (gm)	321.93
W_{SI} (gm)	465.35
H_{SI} (cm)	1.235

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.38
e	8.008
X_{WE} (%)	365

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.38
H_f (IN)	4,15
e	7.537
X_{WE} (%)	344

TIME (MIN)	DIAL READING (10^{-3} IN)
0	294
0.10	323
0.25	346
0.5	372
0.75	392
1.0	408
2	453
4	504
8	555
16	597
30	627
45	645
60	656

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.15
H_f (IN)	3.82
e	6.852
X_{WE}(%)	313

TIME (MIN)	DIAL READING (10^{-3} IN)
0	290
0.10	355
0.50	402
0.75	428
1.0	447
2	497
4.5	571
8	625
16	681
30	717
45	735
60	746

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.82
H_f (IN)	3.57
e	6.338
X_{WE}(%)	289

TIME (MIN)	DIAL READING (10^{-3} IN)
0	121
0.10	140
0.25	155
0.50	173
0.75	189
1.0	202
2	240
4	287
8	336
16	379
30	409
45	425
60	435

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 1)

Beaker	B
Date	2-14-78
X_{FI} (%)	24.05
X_{CI} (%)	75.95
X_{FO} (%)	29.63
X_{CO} (%)	70.37
G_{SI}	2.29
W_L (gm)	30.95
W_{tl} (gm)	500
W_t-W_L(gm)	469.05
X_{DI} (%)	24.83
W_{FI} (gm)	64.47
W_{CI} (gm)	330.07
W_{SI} (gm)	434.54
H_{SI} (cm)	1.103

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.80
e	7.751
X_{WE} (%)	338

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.80
H_f (IN)	3.49
e	7.034
X_{WE} (%)	307

TIME (MIN)	DIAL READING (10^{-3} IN)
0	270
0.10	283
0.25	293
0.50	305
0.75	314
1.0	323
2	348
4	382
8	426
17	490
30	544
45	585
60	612

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.49
H_f (IN)	3.14
e	6.242
X_{WE} (%)	273

TIME (MIN)	DIAL READING (10^{-3} IN)
0	528
0.25	578
0.50	593
0.75	605
1.0	617
2	651
4.2	700
8	755
16	824
30	888
45	947
60	927

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.14
H_f (IN)	2.94
e	5.777
X_{WE} (%)	252

TIME (MIN)	DIAL READING (10^{-3} IN)
0	450
0.10	457
0.25	462
0.50	468
0.75	473
1.0	478
2	494
4	515
9	548
16	579
30	616
60	656
80	671
121	690

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 2)

Beaker	C
Date	2-15-78
X_{FI} (%)	17.47
X_{CI} (%)	82.53
X_{FO} (%)	31.64
X_{CO} (%)	68.36
G_{SI}	2.39
W_L (gm)	17.45
W_{tl} (gm)	500
W_t-W_L(gm)	482.55
X_{DI} (%)	54.18
W_{FI} (gm)	69.96
W_{CI} (gm)	329.87
W_{SI} (gm)	399.83
H_{SI} (cm)	0.97
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.13
e	7.196
X_{WE} (%)	300
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.13
H_f (IN)	2.71
e	6.104
X_{WE} (%)	255
TIME (MIN)	DIAL READING (10^{-3} IN)
0	495
0.10	520
0.25	533
0.50	548
0.75	560
1.0	569
2	600
4	650
8	706
16	778
30	854
60	943
PRESS	11.6-23.3gm/cm^2
H_i (IN)	2.71
H_f (IN)	2.50
e	5.536
X_{WE}(%)	231
TIME (MIN)	DIAL READING (10^{-3} IN)
0	465
0.10	472
0.25	479
0.50	486
1.0	499
2	518
4	544
8	577
16	617
30	658
45.4	686
60	705
14	738
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	2.50
H_f (IN)	2.35
e	5.148
X_{WE}(%)	215
TIME (MIN)	DIAL READING (10^{-3} IN)
0	468
0.10	477
0.25	480
0.50	483
0.75	487
1.0	489
2	498
4	511
8	529
16	533
30	578
45	594
60	606
83	616
121	623

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 3)

Beaker	D
Date	2-16-78
X_{FI} (%)	22.52
X_{CI} (%)	77.48
X_{FO} (%)	32.02
X_{CO} (%)	67.98
G_{SI}	2.31
W_L (gm)	17.70
W_{tl} (gm)	500
W_t-W_L(gm)	482.3
X_{DI} (%)	38.32
W_{FI} (gm)	95.25
W_{CI} (gm)	327.87
W_{SI} (gm)	423.12
H_{SI} (cm)	1.065
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.00
e	6.175
X_{WE} (%)	267
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.00
H_f (IN)	2.66
e	5.339
X_{WE} (%)	231
TIME (MIN)	DIAL READING (10^{-3} IN)
0	515
0.10	527
0.25	532
0.50	540
0.75	547
1.0	554
2	574
4	605
9	659
16	707
30	767
60	837
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	2.66
H_f (IN)	2.29
e	4.462
X_{WE}(%)	193
TIME (MIN)	DIAL READING (10^{-3} IN)
0	555
0.25	561
0.50	567
0.75	572
1.0	576
2	592
4	616
8	651
16	700
41	787
60	834
77	859
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	2.29
H_f (IN)	2.08
e	3.959
X_{WE}(%)	171
TIME (MIN)	DIAL READING (10^{-3} IN)
0	515
0.10	520
0.25	523
0.50	527
0.75	530
1.0	532
2	547
4	557
8	579
18	615
34	650
47	670
60	685
81	702
160	737
200	747

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 4)

Beaker	E		F	
Date	2-17-78	Date	2-18-78	
X_{FI} (%)	11.81	X_{FI} (%)	15.54	
X_{CI} (%)	88.19	X_{CI} (%)	84.46	
X_{FO} (%)	30.91	X_{FO} (%)	30	
X_{CO} (%)	69.09	X_{CO} (%)	70	
G_{SI}	2.48	G_{SI}	2.42	
W_L (gm)	10.46	W_L (gm)	14.6	
W_t (gm)	500	W_t (gm)	500	
W_t-W_L (gm)	489.54	$W_t W_L$ (gm)	485.4	
X_{DI} (%)	70.07	X_{DI} (%)	57.07	
W_{FI} (gm)	44.34	W_{FI} (gm)	62.52	
W_{CI} (gm)	338.22	W_{CI} (gm)	339.78	
W_{SI} (gm)	382.56	W_{SI} [gm)	402.30	
H_{SI} (cm)	0.897	H_{SI} (cm)	0.967	

Beaker
Date
X_{FI} (%)
X_{CI} (%)
X_{FO} (%)
X_{CA} (%)
G_{SI}
W_L (gm)
W_{tl} (gm)
W_t-W_L (gm)
X_{DI} (%)
W_{FI} (gm)
W_{CI} (gm)
W_{SI} (gm)
H_{SI} (gm)

No Dial Reading-Time Data, insufficient material remaining after decomposition.

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 5)

Beaker	G
Date	1-29-78
X_{FI} (%)	34.41
X_{CI} (%)	45.59
X_{FO} (%)	39.87
X_{CO} (%)	40.13
G_{SI}	1.92
W_L (gm)	12.27
W_{tl} (gm)	312.5
W_t-W_L(gm)	300.25
X_{DI} (%)	20.00
W_{FI} (gm)	143.80
W_{CI} (gm)	120.48
W_{SI} (gm)	264.28
H_{SI} (cm)	0.800

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.40
e	15.51
X_{WE} (%)	808

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.40
H_f (IN)	4.92
e	14.628
X_{WE} (%)	762

TIME (MIN)	DIAL READING (10^{-3} IN)
0	110
0.10	168
0.25	202
0.50	241
0.75	270
1.0	290
2	348
4	407
8	442
16	473
30	499
49	514
60	523

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.92
H_f (IN)	4.34
e	12.774
X_{WE} (%)	665

TIME (MIN)	DIAL READING (10^{-3} IN)
0	467
0.10	535
0.25	583
0.50	640
1.0	718
2	825
4	943
8	1028
16	1084
30	1124
45	1161
60	1146

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.34
H_f (IN)	3.98
e	11.646
X_{WE} (%)	606

TIME (MIN)	DIAL READING (10^{-3} IN)
0	152
0.10	191
0.25	220
0.50	259
0.75	291
1.0	314
4	445
8	513
19	576
30	600
45	616
60	631

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 6)

Beaker	H
Date	2-20-78
X_{FI} (%)	46.22
X_{CI} (%)	53.78
X_{FO} (%)	59.49
X_{CO} (%)	40.51
G_{SI}	2.00
W_L (gm)	6.65
W_{tl} (gm)	312.5
W_t-W_L(gm)	305.85
X_{DI} (%)	41.48
W_{FI} (gm)	106.48
W_{CI} (gm)	123.9
W_{SI} (gm)	230.38
H_{SI} (cm)	0.670
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.88
e	13.709
X_{WE} (%)	686
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.88
H_f (IN)	3.59
e	12.593
X_{WE} (%)	630
TIME (MIN)	DIAL READING (10^{-3} IN)
0	477
0.10	490
0.25	495
0.50	502
0.75	507
1.0	512
2	528
4	553
8	590
17	644
31	695
45	729
60	754
100	792
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.59
H_f (IN)	3.17
e	11.034
X_{WE} (%)	552
TIME (MIN)	DIAL READING (10^{-3} IN)
0	283
0.10	305
0.25	310
0.50	316
0.75	321
1.0	326
2	343
4	379
8	409
16	469
34	560
45	592
60	624
81	653
100	672
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.17
H_f (IN)	2.91
e	10.025
X_{WE}(%)	501
TIME (MIN)	DIAL READING (10^{-3} IN)
0	219
0.10	232
0.25	236
0.50	239
0.75	242
1.0	244
2	253
4	267
8	288
16	316
32	357
45	402
60	382
81	425
100	440
144	465
196	484
256	497
324	511

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 7)

Beaker	I	J	K	L
Date	2-21-78	2-22-78	2-23-78	2-24-78
X_{FI} (%)	37.4	48.38	40.89	41.37
X_{CI} (%)	67.6	51.62	59.11	58.63
X_{FO} (%)	60.28	60.85	61.00	60.90
X_{CA} (%)	39.72	39.15	39.00	39.1
G_{SI}	2.11	1.98	2.06	2.06
W_L (gm)	7.9	6.65	5.90	6.30
W_{tl} (gm)	312.5	312.5	312.5	312.5
W_t-W_L (gm)	304.6	305.85	306.6	306.20
X_{DI} (%)	60.63	39.7	55.77	54.70
W_{FI} (gm)	72.29	112.22	82.72	84.47
W_{CI} (gm)	120.99	119.74	119.57	119.72
W_{SI} (gm)	193.28	231.96	202.29	204.19
H_{SI} (cm)	0.533	0.681	0.571	0.576

Beaker				
Date				
X_{FI} (%)				
X_{CI} (%)				
X_{FO} (%)				
X_{CA} (%)				
G_{SI}				
W_L (gm)				
W_{tl} (gm)				
W_t-W_L (gm)				
X_{DI} (%)				
W_{FI} (gm)				
W_{CI} (gm)				
W_{SI} (gm)				
H_{SI} (gm)				

No dial reading-time data, insufficient material remaining after decomposition.

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 8)

Beaker	M
Date	2-25-78
X_{FI} (%)	68.14
X_{CI} (%)	31.86
X_{FO} (%)	79.05
X_{CO} (%)	20.95
G_{SI}	1.78
W_L (gm)	5.35
W_{tl} (gm)	225
W_t-W_L(gm)	219.64
X_{DI} (%)	43.32
W_{FI} (gm)	98.411
W_{CI} (gm)	45.905
W_{SI} (gm)	144.32
H_{SI} (cm)	0.471
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.00
e	25.964
X_{WE} (%)	1457
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.00
H_f (IN)	4.60
e	23.800
X_{WE} (%)	1336
TIME (MIN)	DIAL READING (10^{-3} IN)
0	365
0.10	470
0.25	525
0.50	590
0.75	630
1.0	663
2	738
4	802
8	859
16	898
40	938
60	954
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.60
H_f (IN)	4.09
e	21.047
X_{WE}(%)	1181
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	220
0.10	315
0.50	435
0.75	480
1.0	516
2	616
4	705
8	770
16	812
30	841
49	860
60	867
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.09
H_f (IN)	3.84
e	19.730
X_{WE}(%)	1108
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	197
0.10	244
0.25	274
0.50	306
0.75	330
1.0	348
2	396
4	444
8	485
18	523
30	546
45	562
60	573
100	593
140	606

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 9)

Beaker	N
Date	2-26-78
X_{FI} (%)	62.56
X_{CI} (%)	37.44
X_{FO} (%)	79.97
X_{CO} (%)	20.03
G_{SI}	1.84
W_L (gm)	7.78
W_{tl} (gm)	225
W_t-W_L(gm)	217.22
X_{DI} (%)	58.15
W_{FI} (gm)	72.70
W_{CI} (gm)	43.51
W_{SI} (gm)	116.21
H_{SI} (cm)	0.367
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.75
e	24.954
X_{WE} (%)	1355
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.75
H_f (IN)	3.21
e	21.210
X_{WE} (%)	1152
TIME (MIN)	DIAL READING (10^{-3} IN)
0	135
0.10	185
0.25	218
0.5	260
0.75	294
1.0	322
2	407
4	505
8	617
16	709
35	782
49	805
67	817
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.21
H_f (IN)	2.87
e	18.883
X_{WE} (%)	1026
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	245
0.10	350
0.50	416
1	465
2	531
4	594
8	644
16	681
30	707
45	722
60	732
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	2.87
H_f (IN)	2.64
e	17.237
X_{WE}(%)	9.36
TIME (MIN)	DIAL READING (10^{-3} IN)
0	150
0.10	173
0.25	188
0.50	207
0.75	223
1.0	237
2	277
4	323
8	367
16	403
30	431
45	447
60	458
121	481
175	492

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 10)

Beaker	O	P	Q	R
Date	2-27-78	2-28-78	3-1-78	3-2-78
X_{FI} (%)	57.09	61.74	65.35	60.06
X_{CI} (%)	42.91	38.26	34.65	39.94
X_{FO} (%)	80.03	80.40	80.07	80.10
X_{CA} (%)	19.97	19.60	19.93	19.90
G_{SI}	1.89	1.84	1.81	1.86
W_L (gm)	8.12	9.59	8.11	9.12
W_{tl} (gm)	225	225	225	225
W_t-W_L (gm)	216.88	215.41	216.89	215.88
X_{DI} (%)	66.74	60.65	53.06	62.71
W_{FI} (gm)	57.73	68.15	81.52	64.48
W_{CI} (gm)	43.31	42.22	43.23	42.96
W_{SI} (gm)	101.04	110.37	124.75	107.44
H_{SI} (cm)	0.311	0.348	0.401	0.336

Beaker				
Date				
X_{FI} (%)				
X_{CI} (%)				
X_{FO} (%)				
X_{CA} (%)				
G_{SI}				
W_L (gm)				
W_{tl} (gm)				
W_t-W_L (gm)				
X_{DI} (%)				
W_{FI} (gm)				
W_{CI} (gm)				
W_{SI} (gm)				
H_{SI} (gm)				

No dial reading-time data, insufficient material remaining after decomposition.

TABLE B-4 Consoldiation Data, Anaerobic, Stage II. (Continue 11)

Beaker	13
Date	3-15-78
X_{FI} (%)	33.01
X_{CI} (%)	66.99
X_{FO} (%)	29.69
X_{CO} (%)	70.31
G_{SI}	2.16
W_L (gm)	15.92
W_{tl} (gm)	500
W_t-W_L(gm)	484.08
X_{DI} (%)	0
W_{FI} (gm)	143.72
W_{CI} (gm)	340.36
W_{SI} (gm)	484.08
H_{SI} (cm)	1.30

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.43
e	7.65
X_{WE} (%)	413

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.43
H_f (IN)	4.06
e	6.94
X_{WE} (%)	320

TIME (MIN)	DIAL READING (10^{-3} IN)
0	228
0.25	395
0.50	444
0.75	470
1.0	488
2	528
5	576
10	607
16	626
30	646
49	663
60	666
104	690

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.06
H_f (IN)	3.59
e	6.01
X_{WE}(%)	277

TIME (MIN.)	DIAL READING (10^{-3} IN)
0	518
0.10	592
0.25	645
0.50	700
0.75	732
1.0	755
2	814
4	874
9	921
16	952
30	975
45	983
60	992
75	1002

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.59
H_f (IN)	3.24
e	5.33
X_{WE}(%)	246

TIME (MIN.)	DIAL READING (10^{-3} IN)
0	278
0.10	---
0.25	340
0.50	367
0.75	387
1.0	403
2	446
4	493
8	537
16	575
30	602
45	616
60	625

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 12)

Beaker	14
Date	3-16-78
X_{FI} (%)	22.29
X_{CI} (%)	77.71
X_{FO} (%)	30.65
X_{CO} (%)	69.35
G_{SI}	2.31
W_L (gm)	14.59
W_{tl} (gm)	500
W_t-W_L(gm)	485.41
X_{DI} (%)	35.10
W_{FI} (gm)	96.56
W_{CI} (gm)	336.63
W_{SI} (gm)	433.19
H_{SI} (cm)	1.09
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.95
e	8.46
X_{WE} (%)	366

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.95
H_f (IN)	3.54
e	7.25
X_{WE} (%)	314

TIME (MIN)	DIAL READING (10^{-3} IN)
0	420
0.10	490
0.25	530
0.50	570
0.75	598
1.0	619
2	674
4	732
8	796
16	856
30	900
49	927
64	939

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.54
H_f (IN)	3.01
e	6.01
X_{WE} (%)	216

TIME (MIN.)	DIAL READING (10^{-3} IN)
0	442
0.10	512
0.25	553
0.50	598
0.75	628
1.0	653
2	715
4	780
8	843
16	900
30	942
49	966
60	975

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.01
H_f (IN)	2.68
e	5.25
X_{WE} (%)	227

TIME (MIN.)	DIAL READING (10^{-3} IN)
0	278
0.10	307
0.25	323
0.50	343
0.75	358
1.0	370
2	402
4	441
8	484
16	530
32	573
45	592
60	604
114	632

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 13)

Beaker	15
Date	3-17-78
X_{FI} (%)	64.49
X_{CI} (%)	35.51
X_{FO} (%)	61.54
X_{CO} (%)	38.46
G_{SI}	1.82
W_L (gm)	9.36
W_{tl} (gm)	312.5
W_t-W_L(gm)	303.4
X_{DI} (%)	0
W_{FI} (gm)	186.55
W_{CI} (gm)	116.59
W_{SI} (gm)	303.14
H_{SI} (cm)	0.97
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.20
e	12.62
X_{WE} (%)	694
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.20
H_f (IN)	4.76
e	11.47
X_{WE} (%)	632
TIME (MIN)	DIAL READING (10^{-3} IN)
0	405
0.10	500
0.50	615
0.75	648
1.0	670
2	712
4	744
8	768
16	789
30	809
60	840
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.76
H_f (IN)	4.20
e	10.01
X_{WE}(%)	551
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	493
0.10	600
0.25	655
0.50	717
0.75	748
1.0	780
2	854
4	903
8	950
16	986
30	1005
60	1052
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.20
H_f (IN)	3.84
e	9.05
X_{WE}(%)	498
TIME (MIN.)	DIAL READING (10^{-3} IN)
0	472
0.10	531
0.25	572
0.50	610
0.75	640
1.0	655
2	704
4	737
8	770
16	793
30	813
60	840

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 14)

Beaker	16
Date	3-17-78
X_{FI} (%)	46.99
X_{CI} (%)	53.01
X_{FO} (%)	60.06
X_{CO} (%)	39.94
G_{SI}	1.99
W_L (gm)	11.48
W_{tl} (gm)	312.5
W_t-W_L(gm)	301.02
X_{DI} (%)	41.05
W_{FI} (gm)	106.58
W_{CI} (gm)	120.23
W_{SI} (gm)	226.81
H_{SI} (cm)	0.66

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.69
e	17.05
X_{WE} (%)	853

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.69
H_f (IN)	4.30
e	15.53
X_{WE} (%)	777

TIME (MIN)	DIAL READING (10^{-3} IN)
0	420
0.10	505
0.25	555
0.50	600
0.75	626
1.44	670
2	690
4	722
8	746
16	763
30	782
60	816

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.30
H_f (IN)	3.76
e	13.45
X_{WE}(%)	673

TIME (MIN)	DIAL READING (10^{-3} IN)
0	444
0.10	522
0.25	576
0.50	632
0.75	672
1.0	701
2	779
4	842
8	887
16	917
30	942
60	982

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.76
H_f (IN)	3.34
e	11.85
X_{WE}(%)	593

TIME (MIN.)	DIAL READING (10^{-3} IN)
0	370
0.10	409
0.25	439
0.50	470
0.75	491
1.0	510
2	566
4	644
8	698
16	734
30	758
60	781

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 15)

Beaker	17
Date	3-19-78
X_{FI} (%)	77.88
X_{CI} (%)	22.12
X_{FO} (%)	80.27
X_{CO} (%)	19.73
G_{SI}	1.70
W_L (gm)	7.57
W_{tl} (gm)	225
W_t-W_L(gm)	217.46
X_{DI} (%)	13.46
W_{FI} (gm)	151.06
W_{CI} (gm)	42.90
W_{SI} (gm)	193.96
H_{SI} (cm)	0.66

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	5.31
e	19.44
X_{WE} (%)	1138

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.31
H_f (IN)	4.92
e	17.94
X_{WE} (%)	1050

TIME (MIN)	DIAL READING (10^{-3} IN)
0	190
0.10	300
0.25	360
0.50	410
0.75	436
1.0	452
2	482
4	505
8	523
16	542
30	559
60	579

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.92
H_f (IN)	4.35
e	15.76
X_{WE}(%)	922

TIME (MIN)	DIAL READING (10^{-3} IN)
0	238
0.10	430
0.25	516
0.50	583
0.75	620
1.0	642
2	686
4	716
8	742
16	764
30	783
60	805
131	831

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.35
H_f (IN)	4.07
e	14.68
X_{WE}(%)	859

TIME (MIN)	DIAL READING (10^{-3} IN)
0	386
0.10	445
0.25	481
0.50	513
0.75	531
1.0	544
2	571
4	592
8	612
16	631
30	647
49	659
60	664.5
169	692.5

TABLE B-4 Consolidation Data, Anaerobic, Stage II. (Continue 16)

Beaker	18
Date	3-20-78
X_{FI} (%)	61.35
X_{CI} (%)	38.65
X_{FO} (%)	80.04
X_{CO} (%)	19.96
G_{SI}	1.85
W_L (gm)	9.21
W_{tl} (gm)	225
W_t-W_L(gm)	215.79
X_{DI} (%)	60.42
W_{FI} (gm)	68.36
W_{CI} (gm)	43.07
W_{SI} (gm)	111.43
H_{SI} (cm)	0.35

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	4.50
e	31.66
X_{WE} (%)	1710

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.50
H_f (IN)	4.07
e	28.54
X_{WE} (%)	1542

TIME (MIN)	DIAL READING (10^{-3} IN)
0	237
0.10	348
0.25	405
0.50	455
0.75	486
1.0	507
2	550
4	582
9	609
16	622
30	640
60	666

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.07
H_f (IN)	3.43
e	23.86
X_{WE}(%)	1289

TIME (MIN)	DIAL READING (10^{-3} IN)
0	410
0.25	630
0.50	710
0.75	765
1.0	800
2	880
4	940
8	977
16	1000
30	1020
60	1055

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.43
H_f (IN)	3.00
e	20.80
X_{WE}(%)	1124

TIME (MIN)	DIAL READING (10^{-3} IN)
0	380
0.10	442
0.25	480
0.50	521
0.75	550
1.0	576
2	642
4	687
8	720
16	751
30	775
45	790
60	802

TABLE B-5 Consolidation Data, Aerobic, Stage II

Beaker	1
Date	3-3-78
X_{FI} (%)	26.69
X_{CI} (%)	73.31
X_{FO} (%)	30.40
X_{CO} (%)	69.6
G_{SI}	2.248
W_L (gm)	8.52
W_{tl} (gm)	750
W_t-W_L(gm)	741.48
X_{DI} (%)	16.65
W_{FI} (gm)	187.88
W_{CI} (gm)	516.07
W_{SI} (gm)	703.95
H_{SI} (cm)	1.821

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	3.56
e	3.97
X_{WE} (%)	177

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	3.56
H_f (IN)	3.37
e	3.7
X_{WE} (%)	165

TIME (MIN)	DIAL READING (10^{-3} IN)
0	180
0.10	192
0.25	195
0.50	199
0.75	203
1.0	206
2	216
4	230
8	249
16	274
30	301
45	324
60	341
100	372

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	3.37
H_f (IN)	3.09
e	3.31
X_{WE} (%)	147

TIME (MIN)	DIAL READING (10^{-3} IN)
0	245
0.10	262
0.25	268
0.50	275
0.75	---
1.0	286
2	301
4	321
8	349
16	387
30	430
45	485
60	462
90	519

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.09
H_f (IN)	2.80
e	2.90
X_{WE}(%)	129

TIME (MIN)	DIAL READING (10^{-3} IN)
0	187
0.10	194
0.25	196
0.5	199
0.75	201
1.0	203
2	209
4	220
8	236
16	260
32	295
49	322
60	337
81	361
100	377
126	395
154	411
196	430
225	439
256	449
289	458

TABLE B-5 Consolidation Data, Aerobic, Stage II. (Continue 1)

Beaker	2
Date	3-4-78
X_{FI} (%)	19.34
X_{CI} (%)	80.66
X_{FO} (%)	30.3
X_{CO} (%)	69.71
G_{SI}	2.36
W_L (gm)	12.22
W_{tl} (gm)	750
W_t-W_L(gm)	737.78
X_{DI} (%)	44.85
W_{FI} (gm)	123.29
W_{CI} (gm)	514.31
W_{SI} (gm)	637.60
H_{SI} (cm)	1.57
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	2.90
e	3.69
X_{WE} (%)	156
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	2.90
H_f (IN)	2.52
e	3.08
X_{WE} (%)	130
TIME (MIN)	DIAL READING (10^{-3} IN)
0	628
0.5	662
0.75	663.5
1.0	665
2	669
5	678
8	685
16	700
30	720
45	736
60	750
81	767
100	782
150	812
169	822
196	835
225	847
256	859
289	871
324	882
364	894
400	903
441	913
750	965
1390	1012
1444	1013.5
PRESS.	11.6-23.3gm/cm^2
H_i (IN)	2.52
H_f (IN)	2.30
e	2.72
X_{WE}(%)	115
TIME (MIN)	DIAL READING (10^{-3} IN)
0	178
2	197
4	201
9	205
16	211
36	230
81	256
144	282
225	303
324	327
416	341
529	360
625	372
1048	401
1225	409
1330	410
PRESS.	23.3-34.9gm/cm^2
H_i (IN)	2.30
H_f (IN)	2.17
e	2.52
X_{WE}(%)	107
TIME (MIN)	DIAL READING (10^{-3} IN)
0	570
1.0	580
4	588
16	606
36	623
64	640
121	662
169	675
256	688
324	570

TABLE B-5 Consolidation Data, Aerobic, Stage II. (Continue 2)

Beaker	3				
Date	3-5-78				
X_{FI} (%)	15.54				
X_{CI} (%)	84.46				
X_{FO} (%)	30.18				
X_{CO} (%)	69.82				
G_{SI}	2.20				
W_L (gm)	11.32				
W_{tl} (gm)	750				
W_t-W_L(gm)	738.68				
X_{DI} (%)	57.43				
W_{FI} (gm)	94.90				
W_{CI} (gm)	515.75				
W_{SI} (gm)	610.65				
H_{SI} (cm)	1.61				
PRESS	0-5.81gm/cm^2				
H_i (IN)					
H_f (IN)					
e					
X_{WE} (%)					
TIME	DIAL READING				
OMITTED					
PRESS	5.8-11.6gm/cm^2				
H_i (IN)					
H_f (IN)					
e					
X_{WE} (%)					
TIME (MIN)	DIAL READING (10^{-3} IN)				

No dial reading-time. Insufficient material remaining after decomposition.

TABLE B-5 Consolidation Data, Aerobic, Stage II. (Continue 3)

Beaker	4
Date	3-6-78
X_{FI} (%)	16.88
X_{CI} (%)	83.12
X_{FO} (%)	29.85
X_{CO} (%)	70.15
G_{SI}	2.4
W_L (gm)	10.78
W_{tl} (gm)	750
W_t-W_L(gm)	739.22
X_{DI} (%)	52.27
W_{FI} (gm)	105.32
W_{CI} (gm)	518.56
W_{SI} (gm)	623.88
H_{SI} (cm)	1.51

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H_f (IN)	2.63
e	3.42
X_{WE} (%)	143

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	2.63
H_f (IN)	2.52
e	3.23
X_{WE} (%)	135

TIME (MIN)	DIAL READING (10^{-3} IN)
0	590
1.0	596
4.0	606
16	628
64	665
129	690
196	703
260	717

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	2.52
H_f (IN)	2.34
e	2.94
X_{WE}(%)	122

TIME (MIN)	DIAL READING (10^{-3} IN)
0	180
1	191
2	197
4	205
9	219
16	231
36	254
64	276
100	299
121	307
487	391
725	412
784	415

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	2.34
H_f (IN)	2.25
e	2.79
X_{WE}(%)	116

TIME (MIN)	DIAL READING (10^{-3} IN)
0	517
1.0	528
2	533
4	540
9	551
16	561
49	586
64	593
144	617
196	626
296	638

TABLE B-5 Consolidation Data, Aerobic, Stage II. (Continue 4)

Beaker	5	6	7	8
Date	3-7-78	3-8-78	3-9-78	3-10-78
X_{FI} (%)	38.05	28.51	26.22	28.37
X_{CI} (%)	61.95	71.49	73.78	71.68
X_{FO} (%)	59.96	60.73	60.56	59.97
X_{CA} (%)	40.04	39.27	39.45	40.03
G_{SI}	2.10	2.22	2.25	2.23
W_L (gm)	8.67	7.94	8.85	7.89
W_{tl} (gm)	500	500	500	500
W_t-W_L (gm)	491.33	492.06	491.15	492.11
X_{DI} (%)	58.98	74.21	76.86	73.55
W_{FI} (gm)	120.85	77.07	68.83	78.06
W_{CI} (gm)	296.73	193.23	193.76	196.99
W_{SI} (gm)	317.58	270.30	262.59	275.05
H_{SI} (cm)	0.88	0.71	0.68	0.72

Beaker	9	10	11	12
Date	3-11-78	3-12-78	3-13-78	3-14-78
X_{FI} (%)	48.14	45.35	36.07	40.04
X_{CI} (%)	51.86	54.65	63.93	59.96
X_{FO} (%)	80.51	79.91	80.16	80.38
X_{CA} (%)	19.49	20.09	19.84	19.63
G_{SI}	1.98	2.01	2.12	2.07
W_L (gm)	8.12	7.34	7.12	7.71
W_{tl} (gm)	350	350	350	350
W_t-W_L (gm)	341.88	342.66	342.88	342.29
X_{DI} (%)	77.53	79.14	86.04	83.70
W_{FI} (gm)	61.85	57.12	38.37	44.85
W_{CI} (gm)	66.63	68.84	68.03	67.19
W_{SI} (gm)	128.48	125.96	106.40	112.04
H_{SI} (cm)	0.38	0.36	0.29	0.31

No dial reading - time data, insufficient material remaining after decomposition.

TABLE B-6 Consolidation Data, Anaerobic, Stage III - O

Beaker	A_1
Date	4-4-78
X_{FI} (%)	30.71
X_{CI} (%)	69.29
X_{FO} (%)	30.71
X_{CA} (%)	69.29
G_{SI}	2.19
W_L (gm)	0
W_{tl} (gm)	500
$W_t - W_L$ (gm)	500
X_{DI} (%)	0
W_{FI} (gm)	153.55
W_{CI} (gm)	346.45
W_{SI} (gm)	500
H_{SI} (cm)	1.33
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.75
e	8.09
X_{WE} (%)	369

TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.29
e	7.21
X_{WE} (%)	329
TIME (MIN)	DIAL READING (10^{-3} IN)
0	191
.25	256
.75	285
1.0	303
2	320
4	367
8	426
16	494
30	558
60	606
PRESS	651
H_i (IN)	11.6-23.3gm/cm^2
H_f (IN)	4.29
e	3.83
X_{WE} (%)	6.34
TIME (MIN)	289
0	DIAL READING (10^{-3} IN)
.25	211
.50	290
.75	318
1.0	341
2	357
4.5	405
9	473
16	537
30	585
60	627
PRESS.	668
H_i (IN)	23.3-34.9gm/cm^2
H_f (IN)	3.83
e	3.59
X_{WE} (%)	5.86
TIME (MIN)	2.68
0	DIAL READING (10^{-3} IN)
.25	300
.50	337
.75	350
1.0	360
2	369
4	393
8	421
16	453
30	488
60	518
PRESS.	548
H_i (IN)	34.9-46.5gm/cm^2
H_f (IN)	3.59
e	3.37
X_{WE} (%)	5.45
TIME (MIN)	249
0	DIAL READING (10^{-3} IN)
.25	36
.50	62
.75	73
1.21	80
2	92
4.5	106
8	136
16	161
30	194
60	222
96	254
206	274
	305

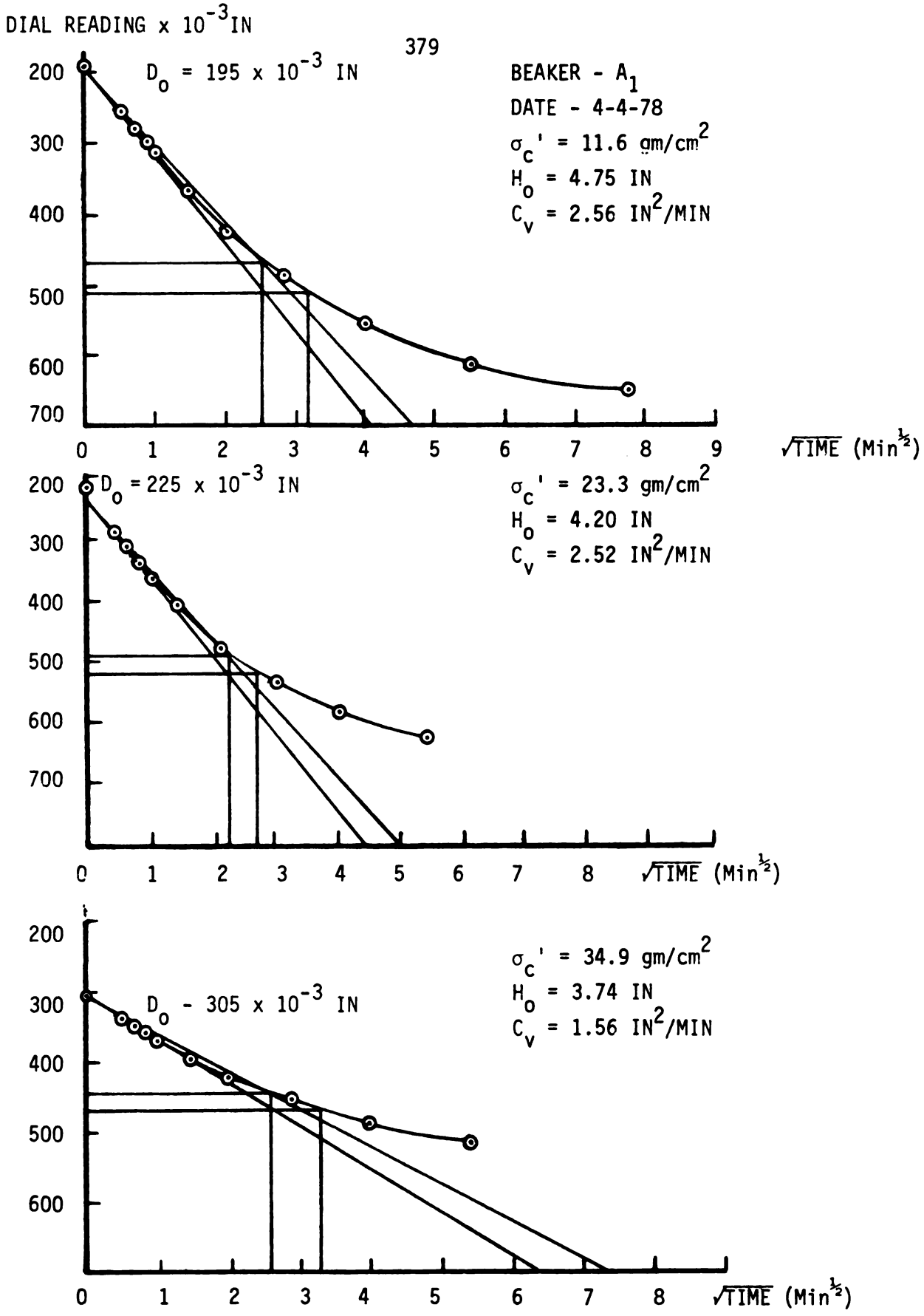

DIAL READING x 10^{-3}IN
D_o = 195 x 10^{-3} IN
BEAKER - A_1
DATE - 4-4-78
σ_c' = 11.6 gm/cm^2
H_o = 4.75 IN
C_v = 2.56 IN^2/MIN
200
300
400
500
600
700
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)
D_o = 225 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.20 IN
C_v = 2.52 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
D_o - 305 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.74 IN
C_v = 1.56 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-6 Consolidation Data, Anaerobic, Stage III - O. (Continue 1)

Beaker	A_5
Date	7-3-78
X_{FI} (%)	30.56
X_{CI} (%)	69.54
X_{FO} (%)	30.46
X_{CA} (%)	69.54
G_{SI}	2.20
W_L (gm)	0
W_{tl} (gm)	500
$W_t - W_L$ (gm)	500
X_{DI} (%)	0
W_{FI} (gm)	152.30
W_{CI} (gm)	347.70
W_{SI} (gm)	500
H_{SI} (cm)	1.32

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.88
e	8.39
X_{WE} (%)	381

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.88
H_f (IN)	4.42
e	7.51
X_{WE} (%)	341

TIME (MIN)	DIAL READING (10^{-3} IN)
0	110
0.25	178
0.50	207
0.75	---
1.0	245
2	293
4	352
8	418
16	481
36	541
60	575

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.42
H_f (IN)	3.91
e	6.52
X_{WE} (%)	296

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.25	282
0.50	315
0.75	340
1.0	360
2	417
4	480
8	540
16	599
30	650
64	705

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.91
H_f (IN)	3.55
e	5.82
X_{WE} (%)	264

TIME (MIN)	DIAL READING (10^{-3} IN)
0	445
0.25	484
0.50	502
0.75	517
1.0	530
2	567
4	612
8	663
18	721
30	758
60	806

PRESS.	34.9-46.5gm/cm^2
H_i (IN)	3.55
H_f (IN)	3.27
e	
X_{WE} (%)	241

TIME (MIN)	DIAL READING (10^{-3} IN)
0	53
0.25	74
0.50	84
0.75	95
2	123
4	153
8	189
16	227
30	265
81	318
100	330

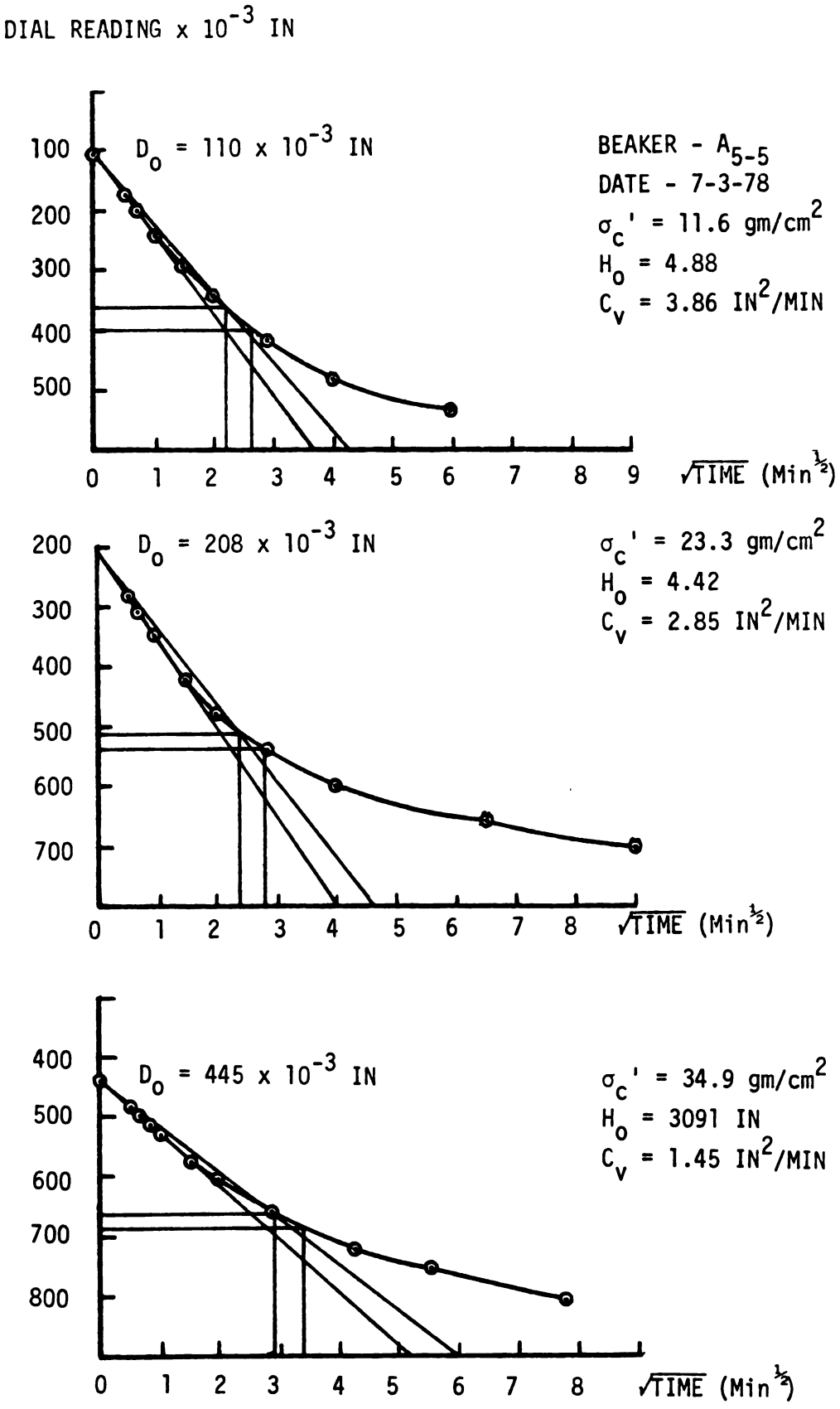

DIAL READING x 10^{-3} IN
100
200
300
400
500
D_o = 110 x 10^{-3} IN
BEAKER - A_{5-5}
DATE - 7-3-78
σ_c' = 11.6 gm/cm^2
H_o = 4.88
C_v = 3.86 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)
200
300
400
500
600
700
D_o = 208 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.42
C_v = 2.85 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
400
500
600
700
800
D_o = 445 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3091 IN
C_v = 1.45 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-6 Consolidation Data, Anaerobic, Stage III - O. (Continue 2)

Beaker	B_1
Date	4-5-78
X_{FI} (%)	57.96
X_{CI} (%)	42.04
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	1.88
W_L (gm)	0
W_{tl} (gm)	312.5
$W_t - W_L$ (gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	181.13
W_{CI} (gm)	131.38
W_{SI} (gm)	312.5
H_{SI} (cm)	0.97

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.19
e	12.59
X_{WE} (%)	672

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.19
H_f (IN)	4.89
e	11.79
X_{WE} (%)	629

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.25	290
.5	320
.75	342
1.0	356
2	389
4	414
8	437
16	458
30	479
60	503

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.89
H_f (IN)	4.43
e	10.60
X_{WE} (%)	566

TIME (MIN)	DIAL READING (10^{-3} IN)
0	208
0.25	345
0.50	388
0.75	416
1.0	438
2	490
4	523
8	570
16	602
32	632
60	666

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.89
H_f (IN)	4.13
e	9.82
X_{WE} (%)	524

TIME (MIN)	DIAL READING (10^{-3} IN)
0	222
0.25	302
.50	325
.75	340
1.0	350
2	380
4	408
8	435
16	461
30	486
64	519

PRESS.	34.9-46.5gm/cm^2
H_i (IN)	4.13
H_f (IN)	3.89
e	9.20
X_{WE} (%)	491

TIME (MIN)	DIAL READING (10^{-3} IN)
0	80
.25	127
.50	145
.75	157
1.0	166
2	188
4	212
8	237
16	262
30	286
45	315
60	303
150	351

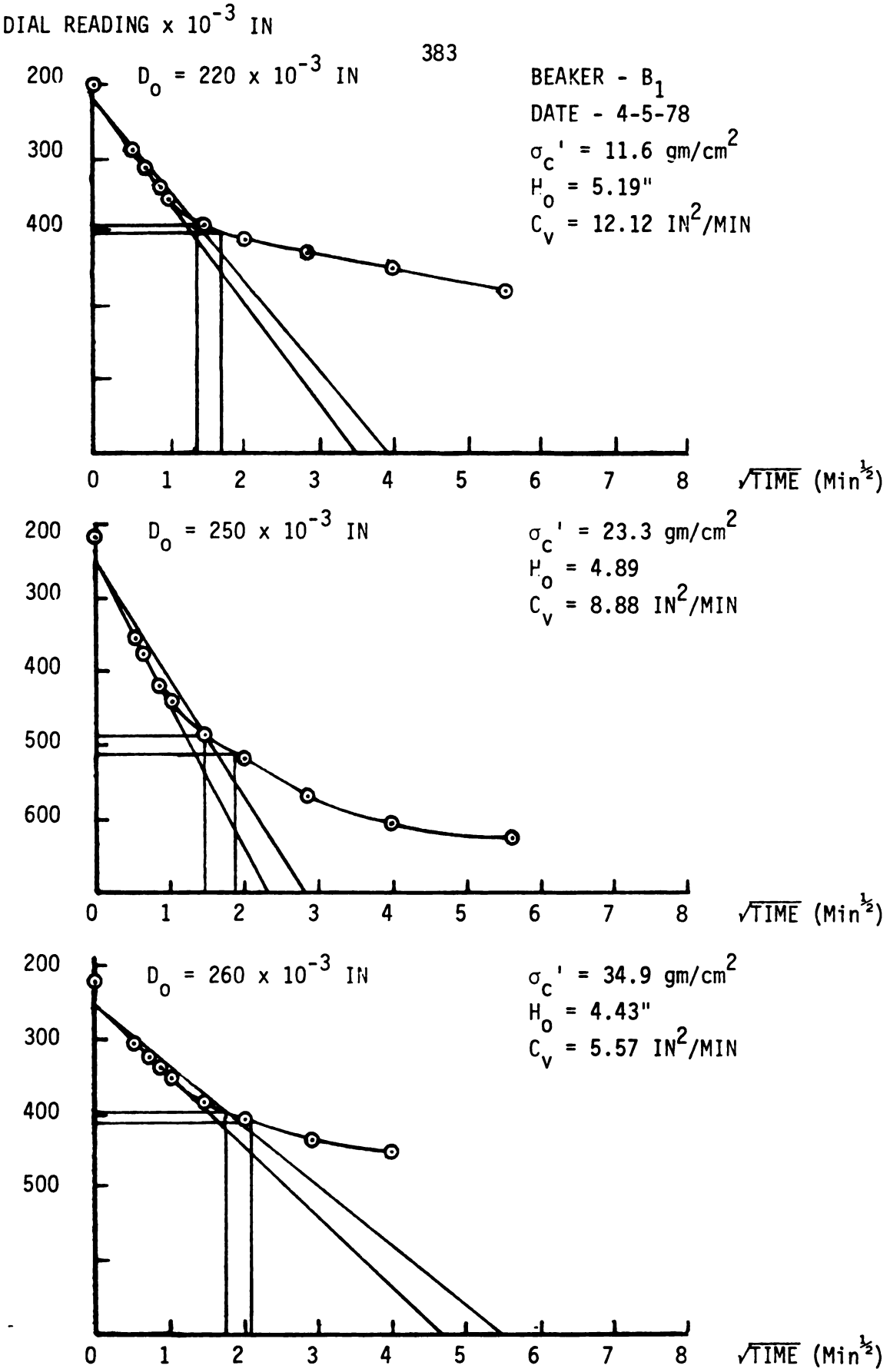

DIAL READING x 10^{-3} IN
200
300
400
D_o = 220 x 10^{-3} IN
BEAKER - B_1
DATE - 4-5-78
σ_c' = 11.6 gm/cm^2
H_o = 5.19"
C_v = 12.12 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
300
400
500
600
D_o = 250 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.89
C_v = 8.88 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
300
400
500
D_o = 260 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 4.43"
C_v = 5.57 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-6 Consolidation Data, Anaerobic, Stage III - O. (Continue 3)

Beaker	B_5
Date	7-4-78
X_{FI} (%)	61.51
X_{CI} (%)	38.49
X_{FO} (%)	61.51
X_{CA} (%)	38.49
G_{SI}	1.85
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	0
W_{FI} (gm)	192.22
W_{CI} (gm)	120.28
W_{SI} (gm)	312.5
H_{SI} (cm)	0.98

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.05
e	13.09
X_{WE} (%)	706

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.05
H_f (IN)	4.71
e	11.20
X_{WE}(%)	604

TIME (MIN)	DIAL READING (10^{-3} IN)
0	246
0.25	346
0.50	380
0.75	400
1.0	417
2	454
4	486
9	518
16	539
30	562
60	589

PRESS	11.6-23.3gm/cm^2
H_i(IN)	4.71
H_f(IN)	4.25
e	10.02
X_{WE}(%)	540

TIME (MIN)	DIAL READING (10^{-3} IN)
0	210
0.25	350
0.5	398
0.75	429
1.0	450
2	498
4	542
8	578
19	616
30	635
64	668

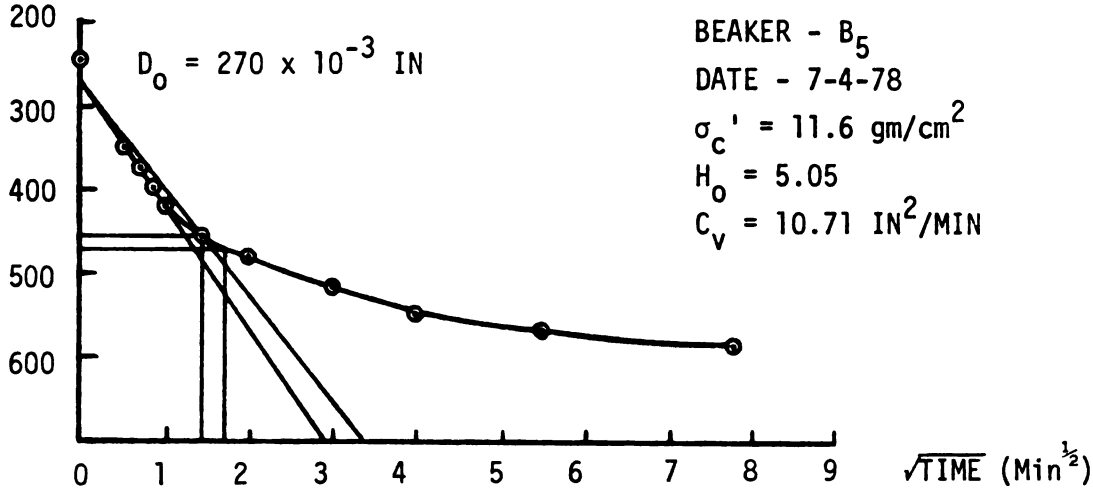
PRESS	23.3-34.9gm/cm^2
H_i(IN)	4.25
H_f(IN)	3.92
e	9.16
X_{WE}(%)	494

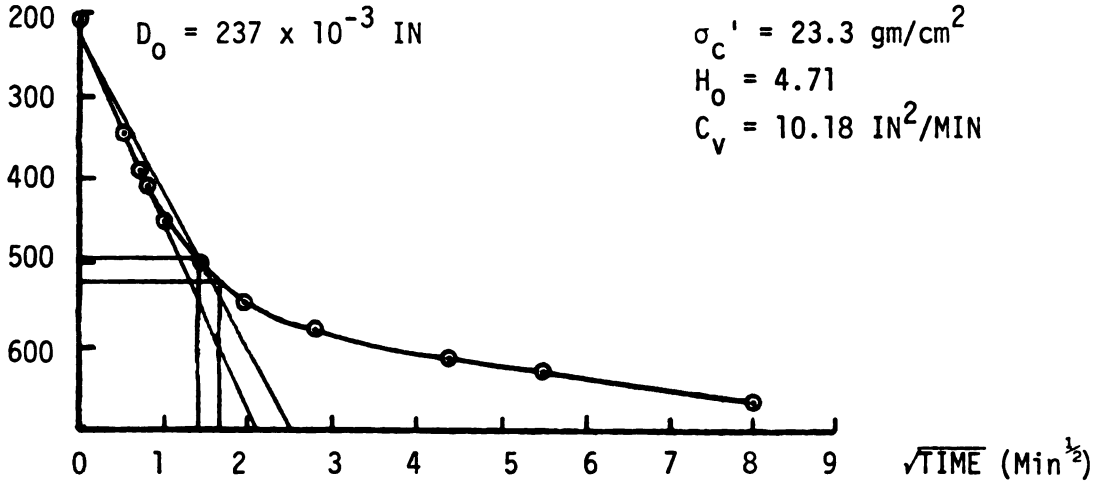
TIME (MIN)	DIAL READING (10^{-3} IN)
0	365
0.25	433
0.50	465
1.0	500
2	538
4.4	581
10	620
16	639
30	666
60	696

PRESS	34.9-46.5gm/cm^2
H_i(IN)	3.92
H_f(IN)	3.66
e	8.44
X_{WE}(%)	458

TIME (MIN)	DIAL READING (10^{-3} IN)
0	360
0.25	409
0.50	430
0.75	445
1.0	456
2	484
4	512
8	542
16	571
30	596
60	---
100	650
121	658

DIAL READING x 10^{-3} IN





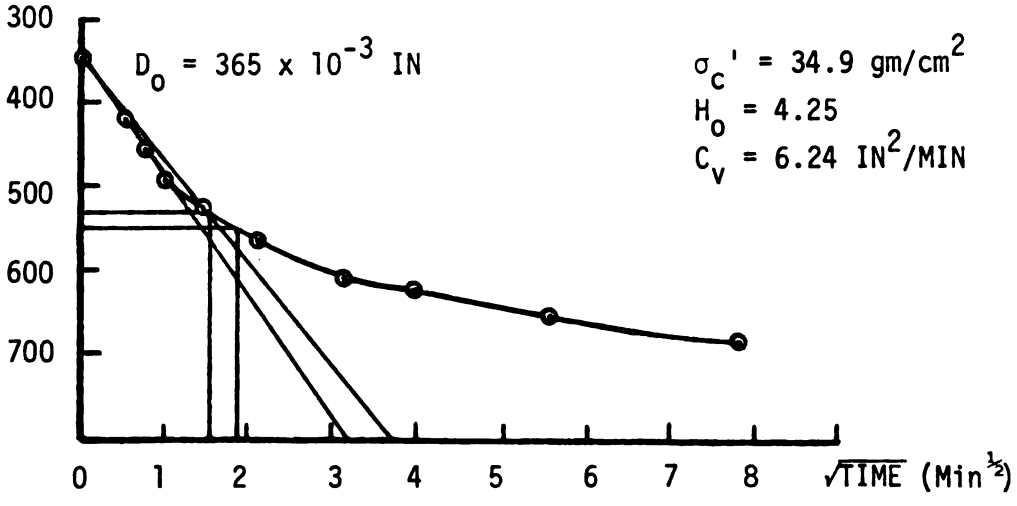


TABLE B-6 Consolidation Data, Anaerobic, Stage III - O. (Continue 4)

Beaker	C_1
Date	4-6-78
X_{FI} (%)	76.57
X_{CI} (%)	23.43
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.71
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	172.28
W_{CI} (gm)	52.72
W_{SI} (gm)	225
H_{SI} (cm)	0.76

PRESS	5.8-11.6gm/cm^2
H_i (IN)	---
H (IN)	5.00
e	15.71
X_{WE} (%)	913

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.00
H_f (IN)	4.75
e	14.87
X_{WE}	864

TIME (MIN)	DIAL READING (10^{-3} IN)
0	458
.25	545
.5	---
.75	583
1.0	592
2	611
4	628
8	646
16	665
30	685
60	710

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.75
H_f (IN)	4.35
e	13.54
X_{WE} (%)	787

TIME (MIN)	DIAL READING (10^{-3} IN)
0	422
.25	564
.50	600
.75	622
1	639
2	677
4	707
8	735
16	764
30	791
60	818

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	4.35
H_f (IN)	4.04
e	12.50
X_{WE} (%)	726

TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
.25	392
.5	420
.75	437
1.0	450
2	481
4	507
8	535
16	561
30	585
60	615

PRESS.	34.9-46.5gm/cm^2
H_i (IN)	4.04
H_f (IN)	3.78
e	11.64
X_{WE} (%)	676

TIME (MIN)	DIAL READING (10^{-3} IN)
0	181
.25	248
.50	268
.75	280
1.0	289
2	311
4	333
8	357
16	382
30	407
45	424
60	436
232	496

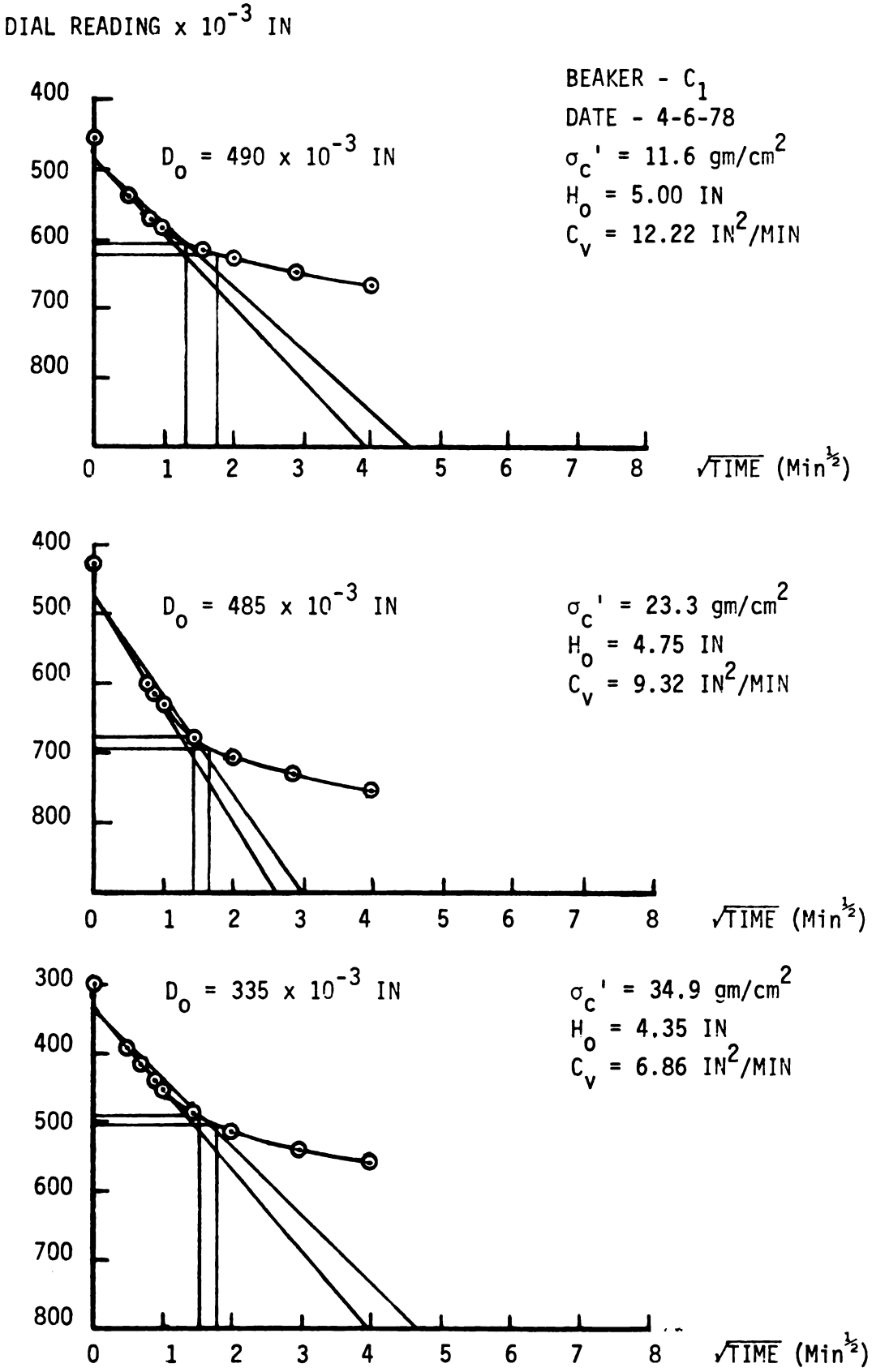

DIAL READING x 10^{-3} IN
BEAKER - C_1
DATE - 4-6-78
σ_c' = 11.6 gm/cm^2
H_o = 5.00 IN
C_v = 12.22 IN^2/MIN
D_o = 490 x 10^{-3} IN
400
500
600
700
800
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
D_o = 485 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.75 IN
C_v = 9.32 IN^2/MIN
D_o = 335 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 4.35 IN
C_v = 6.86 IN^2/MIN
300
400
500
600
700
800

TABLE B-6 Consolidation Data, Anaerobic, Stage III - 0. (Continue 5)

Beaker	C_5
Date	7-5-78
X_{FI} (%)	81.87
X_{CI} (%)	18.13
X_{FO} (%)	81.87
X_{CA} (%)	18.13
G_{SI}	1.67
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	0
W_{FI} (gm)	184.21
W_{CI} (gm)	40.79
W_{SI} (gm)	225
H_{SI} (cm)	0.78
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.00
e	15.28
X_{WE} (%)	911
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i	5.00
H_f	4.59
e	13.95
X_{WE}	832
TIME (MIN)	DIAL READING (10^{-3} IN)
0	362
0.25	477
0.50	527
.75	557
1.0	574
2	610
4	640
8	668
16	696
30	724
60	755
100	777
PRESS	11.6-23.3gm/cm^2
H_i(IN)	4.59
H_f(IN)	4.17
e	12.58
X_{WE}(%)	750
TIME (MIN)	DIAL READING (10^{-3} IN)
0	405
0.25	570
0.50	626
0.75	665
1.0	690
2	742
4	782
8	812
16	847
30	875
60	905
PRESS	23.3-34.9gm/cm^2
H_i(IN)	4.17
H_f(IN)	3.93
e	11.79
X_{WE}(%)	703
TIME (MIN)	DIAL READING (10^{-3} IN)
0	66
0.25	174
0.50	212
0.75	---
1.0	253
2	292
4	326
9	364
19	397
30	418
45	438
60	---
100	477
PRESS	34.9-46.5gm/cm^2
H_i(IN)	3.93
H_f(IN)	3.69
e	11.00
X_{WE}(%)	656
TIME (MIN)	DIAL READING (10^{-3} IN)
0	108
0.25	162
0.50	177
0.75	187
1.0	194
2	214
4	245
8	272
16	297
36	329
60	351

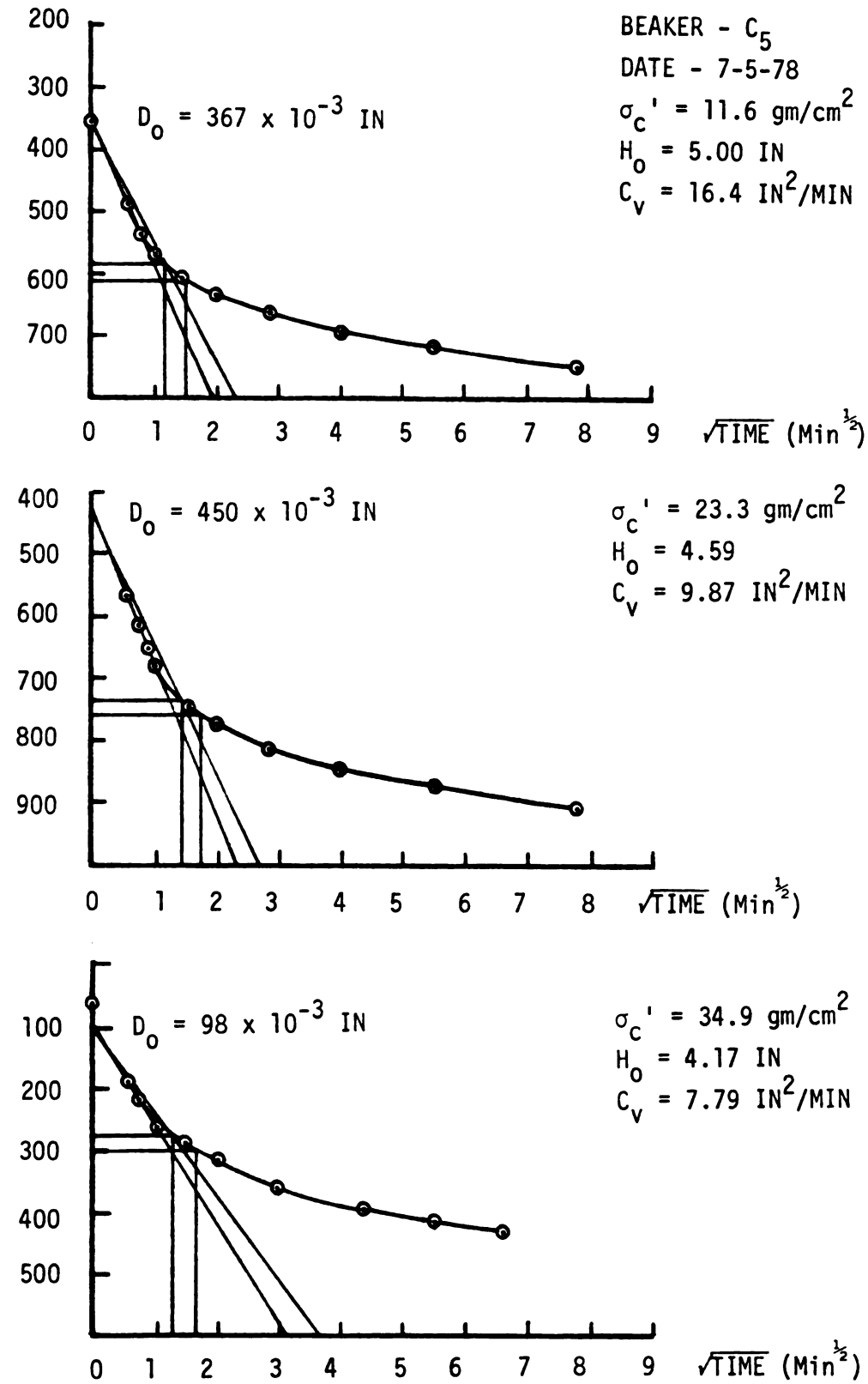

DIAL READING x 10^{-3} IN
200
300
400
500
600
700
D_o = 367 x 10^{-3} IN
BEAKER - C_5
DATE - 7-5-78
σ_c' = 11.6 gm/cm^2
H_o = 5.00 IN
C_v = 16.4 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
400
500
600
700
800
900
D_o = 450 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.59
C_v = 9.87 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
100
200
300
400
500
D_o = 98 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 4.17 IN
C_v = 7.79 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-7* Consolidation Data, Anaerobic, Stage III - 1

Beaker	A_1
Date	4-11-78
X_{FI} (%)	30.66
X_{CI} (%)	69.34
X_{FO} (%)	30.71
X_{CA} (%)	69.29
G_{SI}	2.19
W_L (gm)	17.2
W_{tl} (gm)	500
W_t-W_L(gm)	482.80
X_{DI} (%)	0.23
W_{FI} (gm)	147.93
W_{CI} (gm)	334.53
W_{SI} (gm)	482.46
H_{SI} (cm)	1.28

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.88
e	8.68
X_{WE} (%)	396

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.88
H_f (IN)	4.41
e	7.74
X_{WE}	353

TIME (MIN)	DIAL READING (10^{-3} IN)
0	383
.25	455
	482
	503
1.0	520
2	566
4.30	625
8	680
16	745
30	803
60	851

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.41
H_f (IN)	3.88
e	6.70
X_{WE} (%)	306

TIME (MIN)	DIAL READING (10^{-3} IN)
0	320
.25	412
.50	488
.75	---
1.0	490
2	540
4	594
9	669
16	728
30	791
60	849

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.88
H_f (IN)	3.50
e	5.94
X_{WE} (%)	271

TIME (MIN)	DIAL READING (10^{-3} IN)
0	322
.25	365
.50	382
.75	395
1.0	406
2	440
4	480
8	531
16	589
30	643
60	708

PRESS.	34.9-46.5gm/cm^2
H_i (IN)	3.50
H_f (IN)	3.22
e	5.39
X_{WE} (%)	246

TIME (MIN)	DIAL READING (10^{-3} IN)
0	60
.25	86
.50	97
.75	104
1.0	111
2.5	135
4	157
8	192
16	233
30	285
45	317
61	336
81	352
100	365
144	389

*Sodium bicarbonate added before consolidation.

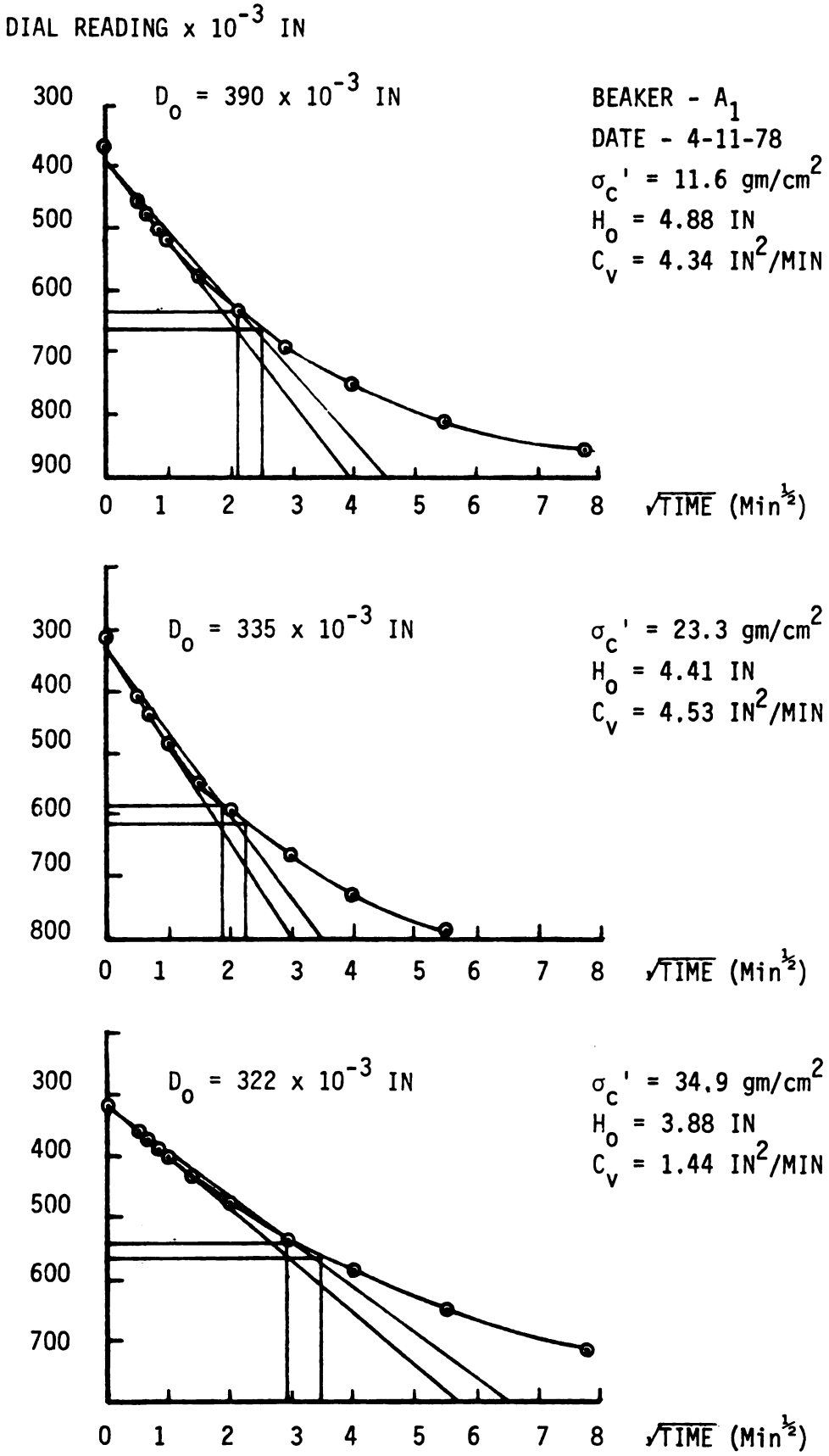

DIAL READING x 10^{-3} IN
300
400
500
600
700
800
900
D_o = 390 x 10^{-3} IN
BEAKER - A_1
DATE - 4-11-78
σ_c' = 11.6 gm/cm^2
H_o = 4.88 IN
C_v = 4.34 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
300
400
500
600
700
800
D_o = 335 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.41 IN
C_v = 4.53 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
300
400
500
600
700
D_o = 322 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.88 IN
C_v = 1.44 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-7 Consolidation Data, Anaerobic, Stage III - 1. (Continue 1)

Beaker	A_5
Date	7-10-78
X_{FI} (%)	28.99
X_{CI} (%)	71.01
X_{FO} (%)	30.46
X_{CA} (%)	69.54
G_{SI}	2.22
W_L (gm)	13.1
W_{tl} (gm)	500
W_t-W_L(gm)	487.90
X_{DI} (%)	6.80
W_{FI} (gm)	138.51
W_{CI} (gm)	339.29
W_{SI} (gm)	477.80
H_{SI} ( )	1.25

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.44
e	8.02
X_{WE} (%)	361

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i	4.44
H_f	4.19
e	7.37
X_{WE}	332

TIME (MIN)	DIAL READING (10^{-3} IN)
0	333
0.25	400
0.5	422
0.75	438
1.0	450
2	486
4	524
9	573
16	603
30	630
60	656

PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.19
H_f(IN)	3.79
e	6.70
X_{WE}(%)	301

TIME (MIN)	DIAL READING (10^{-3} IN)
0	225
0.25	300
0.50	331
0.75	353
1.0	381
2	428
4	476
8	529
18	594
30	631
60	671

PRESS.	23.3-34.9gm/cm^2
H_i(IN)	3.79
H_f(IN)	3.56
e	6.23
X_{WE}(%)	280

TIME (MIN)	DIAL READING (10^{-3} IN)
0	268
0.25	307
0.71	320
0.87	329
1.0	338
2	362
4	394
9	440
16	477
30	528
100	593

PRESS.	34.9-46.5gm/cm^2
H_i(IN)	3.56
H_f(IN)	3.32
e	5.75
X_{WE}(%)	259

TIME (MIN)	DIAL READING (10^{-3} IN)
0	272
0.25	297
0.50	304
0.75	310
1.0	315
2	332
4	354
9	390
16	422
30	462
60	508

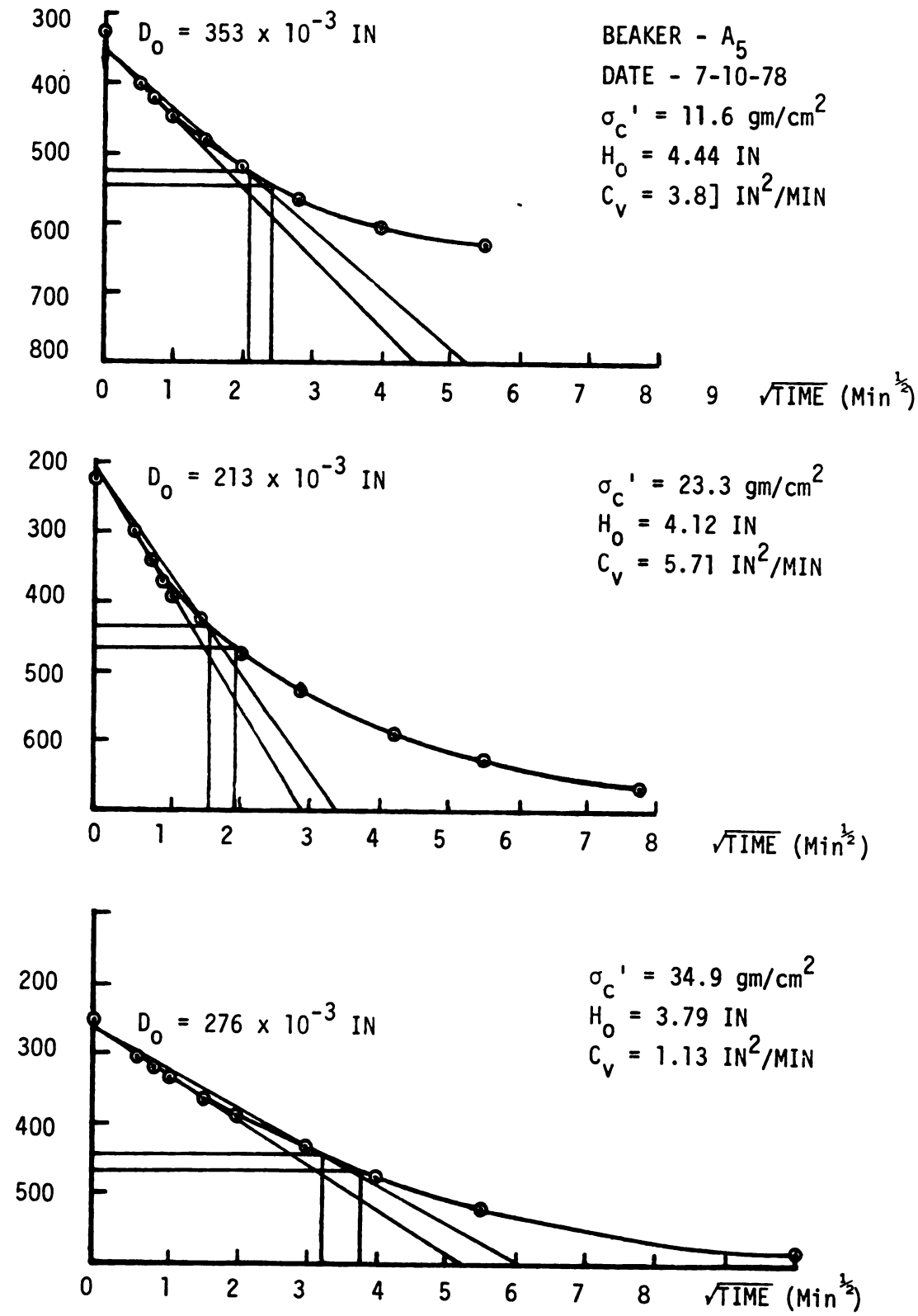

DIAL READING x 10^{-3} IN
300
400
500
600
700
800
D_o = 353 x 10^{-3} IN
BEAKER - A_5
DATE - 7-10-78
σ_c' = 11.6 gm/cm^2
H_o = 4.44 IN
C_v = 3.8] IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
300
400
500
600
D_o = 213 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.12 IN
C_v = 5.71 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
300
400
500
D_o = 276 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.79 IN
C_v = 1.13 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

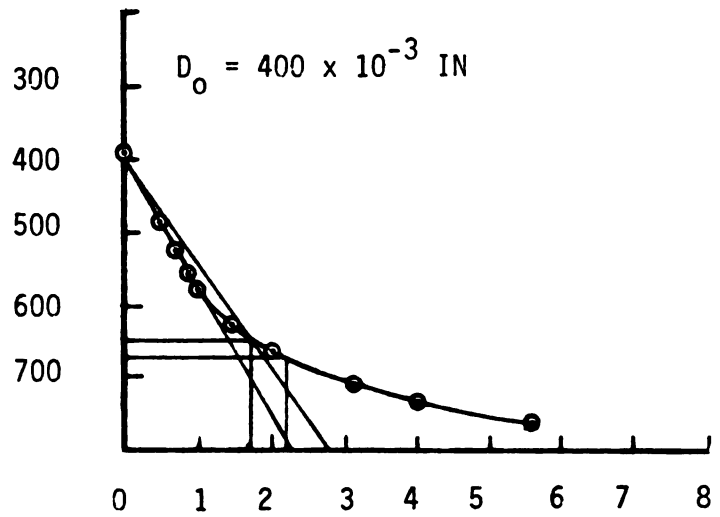
TABLE B-7* Consolidation Data, Anaerobic, Stage III - 1. (Continue 2)

Beaker	B_1
Date	4-12-18
X_{FI} (%)	57.70
X_{CI} (%)	42.29
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	1.88
W_L (gm)	9.85
W_{tl} (gm)	312.5
W_t-W_L(gm)	9.85
X_{DI} (%)	1.06
W_{FI} (gm)	173.56
W_{CI} (gm)	127.23
W_{SI} (gm)	300.79
H_{SI} ( )	0.93
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.32
e	13.53
X_{WE} (%)	720
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i(IN)	5.32
H_f(IN)	4.92
e	12.44
X_{WE}(%)	662
TIME (MIN)	DIAL READING (10^{-3} IN)
0	385
.25	480
.50	520
.75	546
1.0	568
2	621
4	669
9.40	713
16	736
32	762
60	784
PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.92
H_f(IN)	4.37
e	10.94
X_{WE}(%)	582
TIME (MIN)	DIAL READING (10^{-3} IN)
0	345
.25	480
.50	530
.75	566
1.0	593
2	661
4	730
8	---
24	852
30	863
49	887
60	897
PRESS.	23.3-34.9gm/cm^2
H_i(IN)	4.37
H_f(IN)	4.03
e	10.01
X_{WE}(%)	532
TIME (MIN)	DIAL READING (10^{-3} IN)
0	95
.25	152
.50	180
.75	197
1.0	210
2	247
4	287
8	329
17.15	371
30	398
60	434
72	443
PRESS.	34.9-46.5gm/cm^2
H_i(IN)	4.03
H_f(IN)	3.74
e	9.20
X_{WE}(%)	489
TIME (MIN)	DIAL READING (10^{-3} IN)
0	446
.25	488
.50	505
.75	518
1.0	528
2	563
4	599
8	634
16	670
30	704
45	726
60	739
88	756
169	786

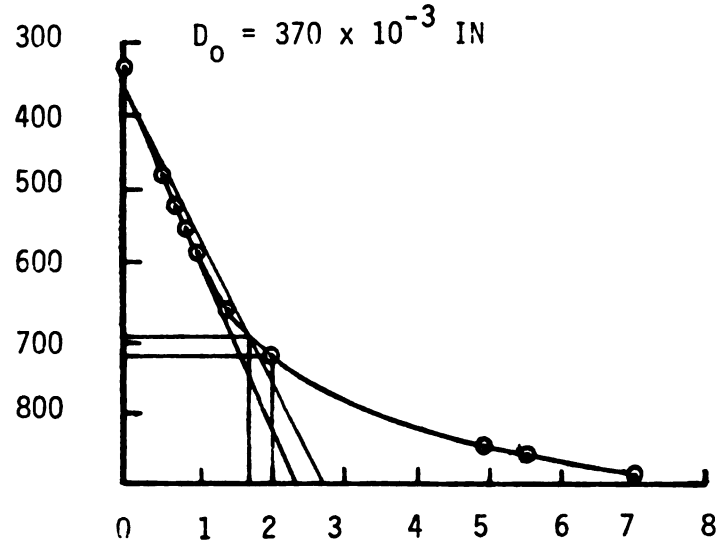
*Sodium bicarbonate added before consolidation.

4-12

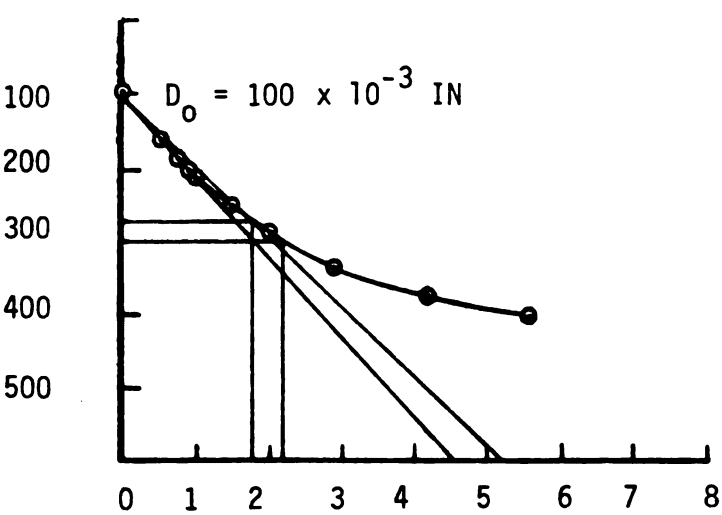
DIAL READING x 10^{-3} IN



BEAKER - B_1
DATE - 4-12-78
σ_c' = 11.6 gm/cm^2
H_o = 5.32"
C_v = 7.96 IN^2/MIN



σ_c' = 23.3 gm/cm^2
H_o = 4.92 IN
C_v = 6.83 IN^2/MIN



σ_c' = 34.9 gm/cm^2
H_o = 4.37 IN
C_v = 4.28 IN^2/MIN

TABLE B-7 Consolidation Data, Anaerobic, Stage III - 1. (Continue 3)

Beaker	B_5
Date	7-11-78
X_{FI} (%)	58.41
X_{CI} (%)	41.59
X_{FO} (%)	61.51
X_{CA} (%)	38.49
G_{SI}	1.88
W_L (gm)	9.9
W_{tl} (gm)	312.5
W_t-W_L(gm)	302.6
X_{DI} (%)	12.12
W_{FI} (gm)	163.57
W_{CI} (gm)	116.43
W_{SI} (gm)	280
H_{SI} (cm)	0.87

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.88
e	13.25
X_{WE} (%)	708

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i	4.88
H_f	4.54
e	12.25
X_{WE}	655

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
0.25	280
0.50	315
0.75	337
1.0	356
2	401
5	449
8	468
19.5	501
30	516
60	543

PRESS	11.6-23.3gm/cm^2
H_i (IN)	4.54
H_f (IN)	4.05
e	10.83
X_{WE} (%)	579

TIME (MIN)	DIAL READING (10^{-3} IN)
0	37
0.25	160
0.50	204
0.75	237
1.0	260
2.50	335
4	374
8	425
16	464
30	493
60	520

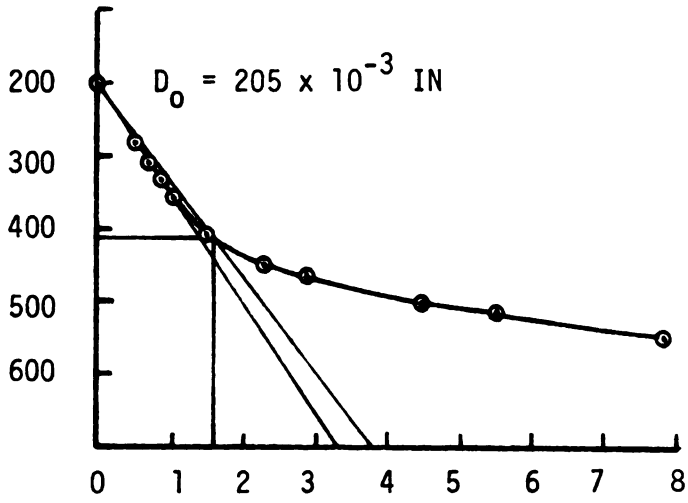
PRESS	23.3-34.9gm/cm^2
H_i (IN)	4.05
H_f (IN)	3.71
e	9.83
X_{WE} (%)	

TIME (MIN)	DIAL READING (10^{-3} IN)
0	338
0.25	397
0.50	421
1.0	451
2	488
4	526
8	567
16	603
36	648
60	681

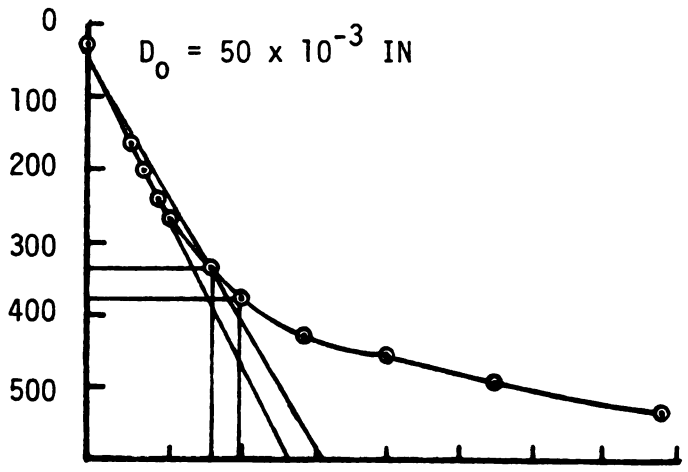
PRESS	34.9-46.5gm/cm^2
H_i (IN)	3.71
H_f (IN)	3.39
e	8.89
X_{WE} (%)	475

TIME (MIN)	DIAL READING (10^{-3} IN)
0	15
0.25	62
0.50	82
0.75	97
1.0	108
2	143
4	180
8	219
16	273
30	314
60	340
125	364

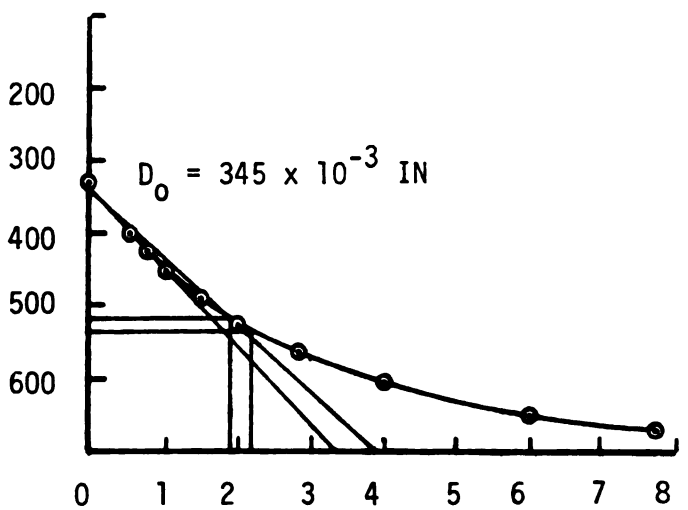
DIAL READING x 10^{-3} IN



BEAKER - B_5
DATE - 7-11-78
σ_c' = 11.6 gm/cm^2
H_o = 4.88 IN
C_v = 7.52 IN^2/MIN



σ_c' = 34.9 gm/cm^2
H_o = 4.54 IN
C_v = 6.28 IN^2/MIN



σ_c' = 34.9 gm/cm^2
H_o = 4.05 IN
C_v = 3.88 IN^2/MIN

TABLE B-7* Consolidation Data, Anaerobic, Stage III - 1. (Continue 4)

Beaker	C_1
Date	4-13-78
X_{FI} (%)	79.06
X_{CI} (%)	20.95
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.69
W_L (gm)	7.2
W_{tl} (gm)	225
W_t-W_L(gm)	217.8
X_{DI} (%)	0
W_{FI} (gm)	172.19
W_{CI} (gm)	45.63
W_{SI} (gm)	217.8
H_{SI} (cm)	0.75

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.38
e	17.23
X_{WE} (%)	1021

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	5.38
H_f(IN)	4.86
e	15.45
X_{WE}	915

TIME (MIN)	DIAL READING (10^{-3} IN)
0	355
.25	460
.5	510
.75	546
1.0	575
2	647
4	713
8	764
16	806
30	835
60	877

PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.86
H_f(IN)	4.26
e	13.43
X_{WE}(%)	795

TIME (MIN)	DIAL READING (10^{-3} IN)
0	180
.25	312
.50	372
.75	415
1.0	447
2	522
4	604
8	661
16	706
30	744
60	784

PRESS.	23.3-34.9gm/cm^2
H_i(IN)	4.26
H_f(IN)	3.86
e	12.07
X_{WE}(%)	715

TIME (MIN)	DIAL READING (10^{-3} IN)
0	348
.25	428
.50	458
.75	483
1.0	508
2	548
4	595
8	636
16	675
30	712
70	756

PRESS.	34.9-46.5gm/cm^2
H_i(IN)	3.86
H_f(IN)	3.65
e	11.15
X_{WE}(%)	672

TIME (MIN)	DIAL READING (10^{-3} IN)
0	10
.25	52
.50	68
.75	80
1.0	88
2	115
4	146
8	185
16	219
30	249
60	282
144	326
169	339

*Sodium bicarbonate added before consolidation.

DIAL READING x 10^{-3} IN

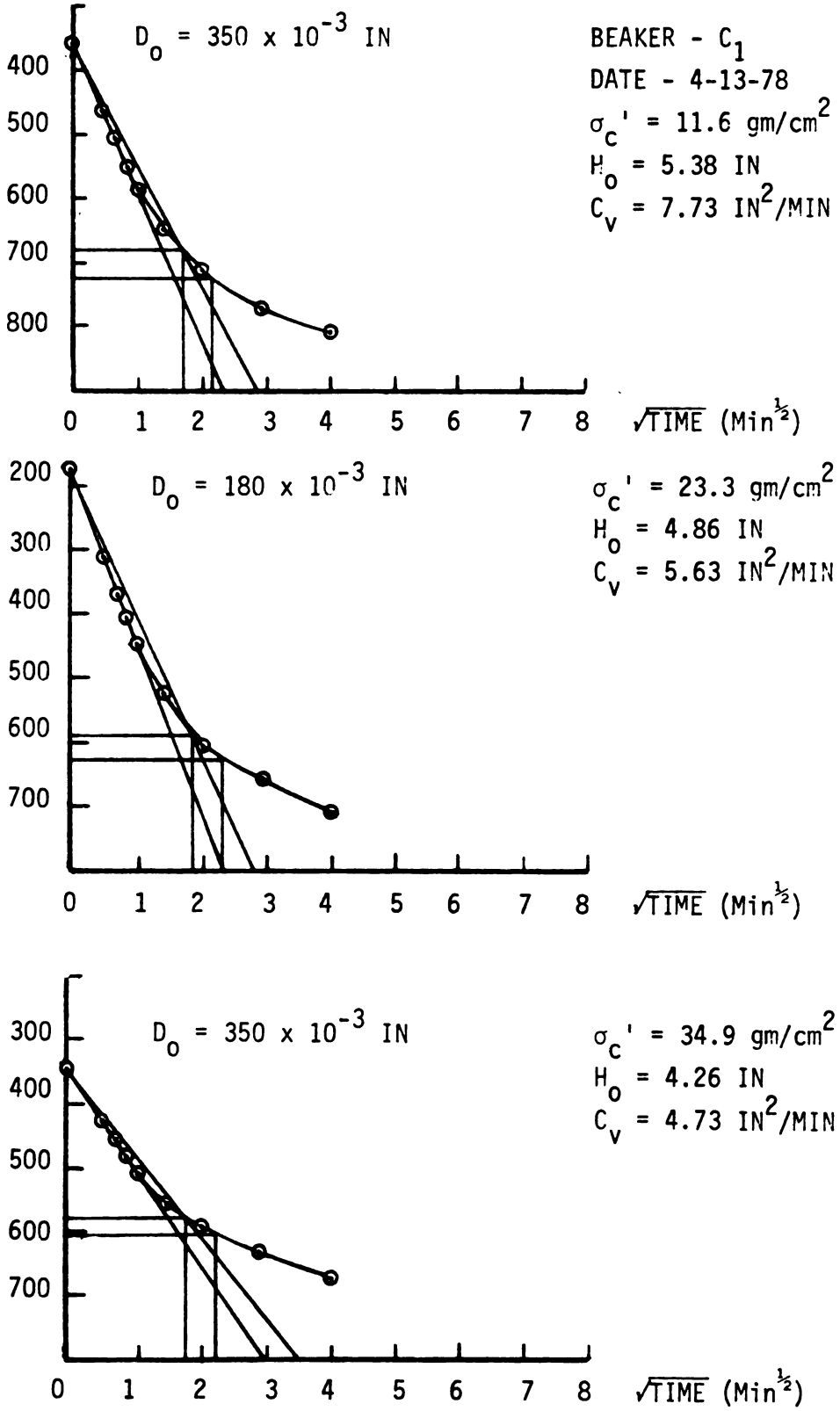


TABLE B-7 Consolidation Data, Anaerobic, Stage III - 1. (Continue 5)

Beaker	C_5
Date	7-12-78
X_{FI} (%)	80.51
X_{CI} (%)	19.49
X_{FO} (%)	81.87
X_{CA} (%)	18.13
G_{SI}	1.68
W_L (gm)	8.3
W_{tl} (gm)	225
W_t-W_L(gm)	216.70
X_{DI} (%)	8.52
W_{FI} (gm)	162.30
W_{CI} (gm)	39.29
W_{SI} (gm)	201.59
H_{SI} ( )	0.70
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.81
e	16.46
X_{WE} (%)	983
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.81
H_f (IN)	4.28
e	14.53
X_{WE}(%)	868
TIME (MIN)	DIAL READING (10^{-3} IN)
0	154
0.25	300
0.75	382
1.0	410
2	477
4	535
8	585
16	621
36	655
60	681
PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.28
H_f(IN)	3.79
e	12.83
X_{WE}(%)	766
TIME (MIN)	DIAL READING (10^{-3} IN)
0	169
0.25	---
0.50	347
0.75	380
1.0	401
2	453
5	520
8	548
16	581
30	608
60	637
PRESS.	23.3-34.9gm/cm^2
H_i(IN)	3.79
H_f(IN)	3.41
e	11.37
X_{WE}(%)	679
TIME (MIN)	DIAL READING (10^{-3} IN)
0	465
0.25	550
0.50	579
0.75	600
1.0	614
2	652
4	698
8	742
16	778
30	808
60	839
121	871
PRESS.	34.9-46.5gm/cm^2
H_i(IN)	3.41
H_f(IN)	3.17
e	10.51
X_{WE}(%)	628
TIME (MIN)	DIAL READING (10^{-3} IN)
0	140
0.25	184
0.50	198
0.75	207
1.0	213
2	230
4	251
8	274
16	317
30	346
64	378

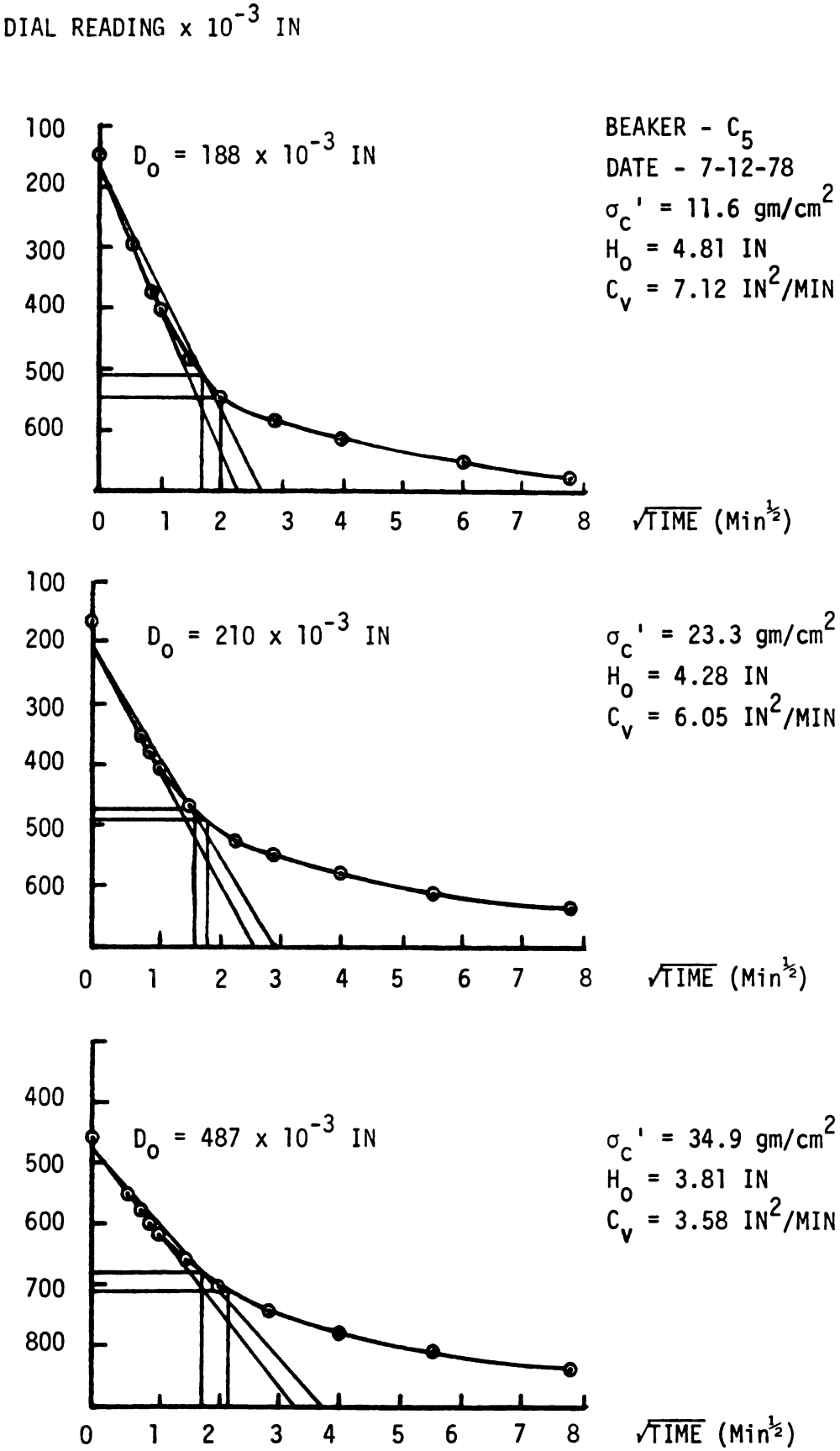

DIAL READING x 10^{-3} IN
100
200
300
400
500
600
D_o = 188 x 10^{-3} IN
BEAKER - C_5
DATE - 7-12-78
σ_c' = 11.6 gm/cm^2
H_o = 4.81 IN
C_v = 7.12 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
100
200
300
400
500
600
D_o = 210 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.28 IN
C_v = 6.05 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
400
500
600
700
800
D_o = 487 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.81 IN
C_v = 3.58 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-8* Consolidation Data, Anaerobic, Stage III - 2

Beaker	A_1
Date	4-18-78
X_{FI} (%)	25.50
X_{CI} (%)	74.50
X_{FO} (%)	30.71
X_{CA} (%)	69.29
G_{SI}	2.26
W_L (gm)	32.60
W_{tl} (gm)	500
W_t-W_L(gm)	467.40
X_{DI} (%)	22.73
W_{FI} (gm)	110.91
W_{CI} (gm)	323.86
W_{SI} (gm)	434.77
H_{SI} (cm)	1.12

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.06
e	10.47
X_{WE} (%)	465

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.06
H_f (IN)	4.54
e	9.29
X_{WE}	412

TIME (MIN)	DIAL READING (10^{-3} IN)
0	260
.25	304
.50	322
.75	337
1.0	350
2	388
4	440
8	507
16	596
30	699
49	793
60	837

PRESS.	11.6-23.3gm/cm^2
H_i (IN)	4.54
H_f (IN)	3.70
e	7.40
X_{WE} (%)	328

TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
.25	343
.50	360
.75	373
1.0	383
2.	415
4	460
8	523
16	614
30	722
60	876
81	946
121	1035
169	1110

PRESS.	23.3-34.9gm/cm^2
H_i (IN)	3.70
H_f (IN)	3.24
e	6.35
X_{WE} (%)	282

TIME (MIN)	DIAL READING (10^{-3} IN)
0	159
.25	185
.50	193
.75	199
1.0	203
2	---
4	243
10	295
16	329
32	398
49	440
64	475
100	529
144	579
200	624
300	678

*Sodium bicarbonate added before consolidation.

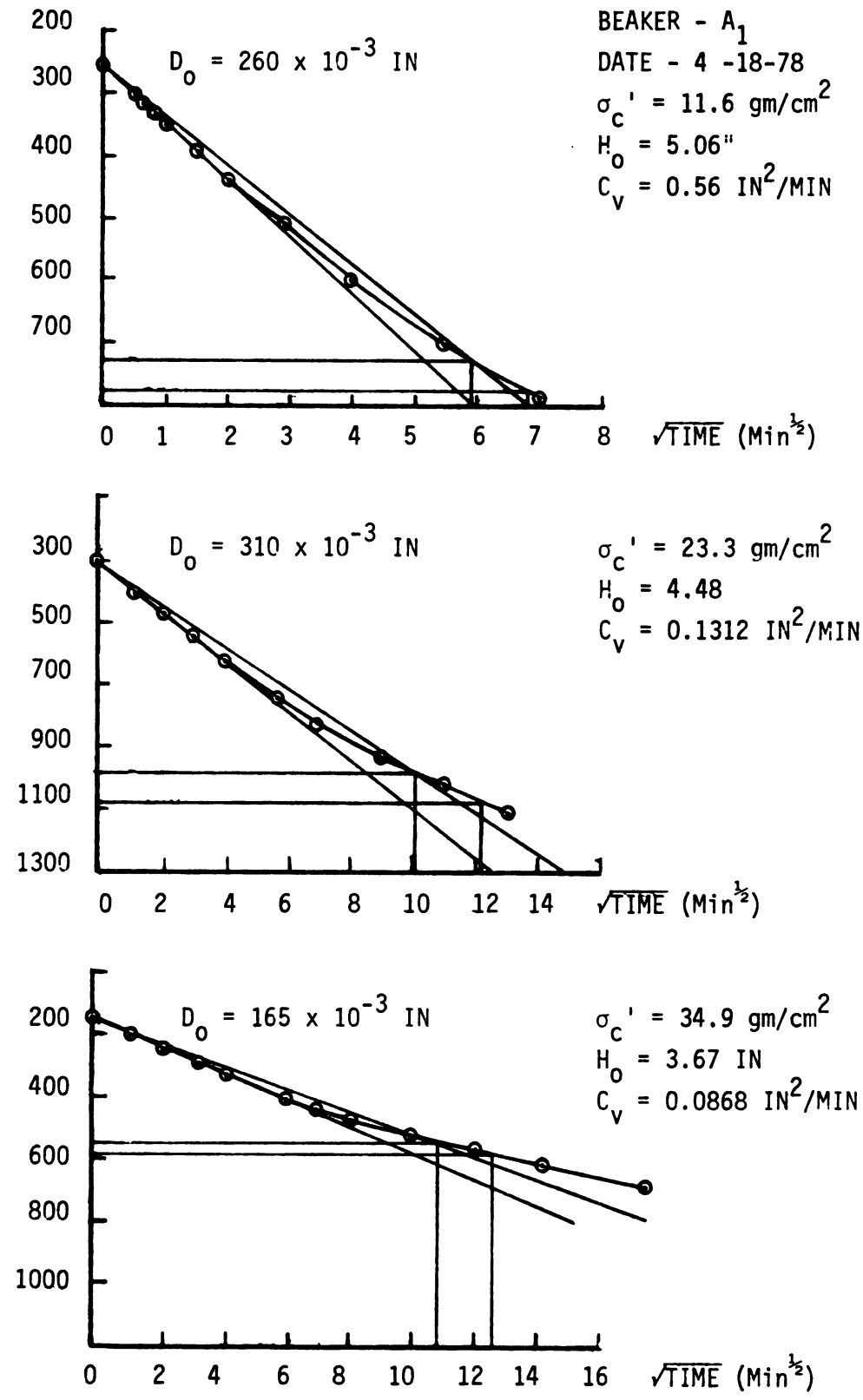

DIAL READING x 10^{-3} IN
200
300
400
500
600
700
D_o = 260 x 10^{-3} IN
BEAKER - A_1
DATE - 4 -18-78
σ_c' = 11.6 gm/cm^2
H_o = 5.06"
C_v = 0.56 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
300
500
700
900
1100
1300
D_o = 310 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.48
C_v = 0.1312 IN^2/MIN
0 2 4 6 8 10 12 14
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
400
600
800
1000
D_o = 165 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.67 IN
C_v = 0.0868 IN^2/MIN
0 2 4 6 8 10 12 14 16
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-8 Consolidation Data, Anaerobic, Stage III - 2. (Continue 1)

Beaker	A_5
Date	7-17-78
X_{FI} (%)	23.96
X_{CI} (%)	76.04
X_{FO} (%)	30.46
X_{CA} (%)	69.54
G_{SI}	2.29
W_L (gm)	34.50
W_{tl} (gm)	500
W_t-W_L(gm)	465.50
X_{DI} (%)	28.06
W_{FI} (gm)	102.00
W_{CI} (gm)	323.71
W_{SI} (gm)	425.71
H_{SI} (cm)	1.08

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	3.63
e	7.54
X_{WE} (%)	329

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	3.63
H_f(IN)	2.97
e	5.98
X_{WE}(%)	261

TIME (MIN)	DIAL READING (10^{-3} IN)
0	278
0.25	305
0.50	319
0.75	331
1.0	341
2	378
4	433
9	523
25	706
36	792
64	897
81	936

PRESS	11.6-23.3gm/cm^2
H_i(IN)	2.97
H_f(IN)	2.68
e	5.31
X_{WE}(%)	232

TIME (MIN)	DIAL READING (10^{-3} IN)
0	70
0.25	98
0.50	105
0.75	---
1.0	114
2	127
4	147
8	177
16	219
60	324
81	350
100	366

PRESS	23.3-34.9gm/cm^2
H_i(IN)	2.68
H_f(IN)	2.45
e	4.76
X_{WE}(%)	208

TIME (MIN)	DIAL READING (10^{-3} IN)
0	390
0.25	405
0.50	408
0.75	411
1.0	413
2	420
4	431
8	449
16	475
30	508
64	555
121	600
144	610
169	620

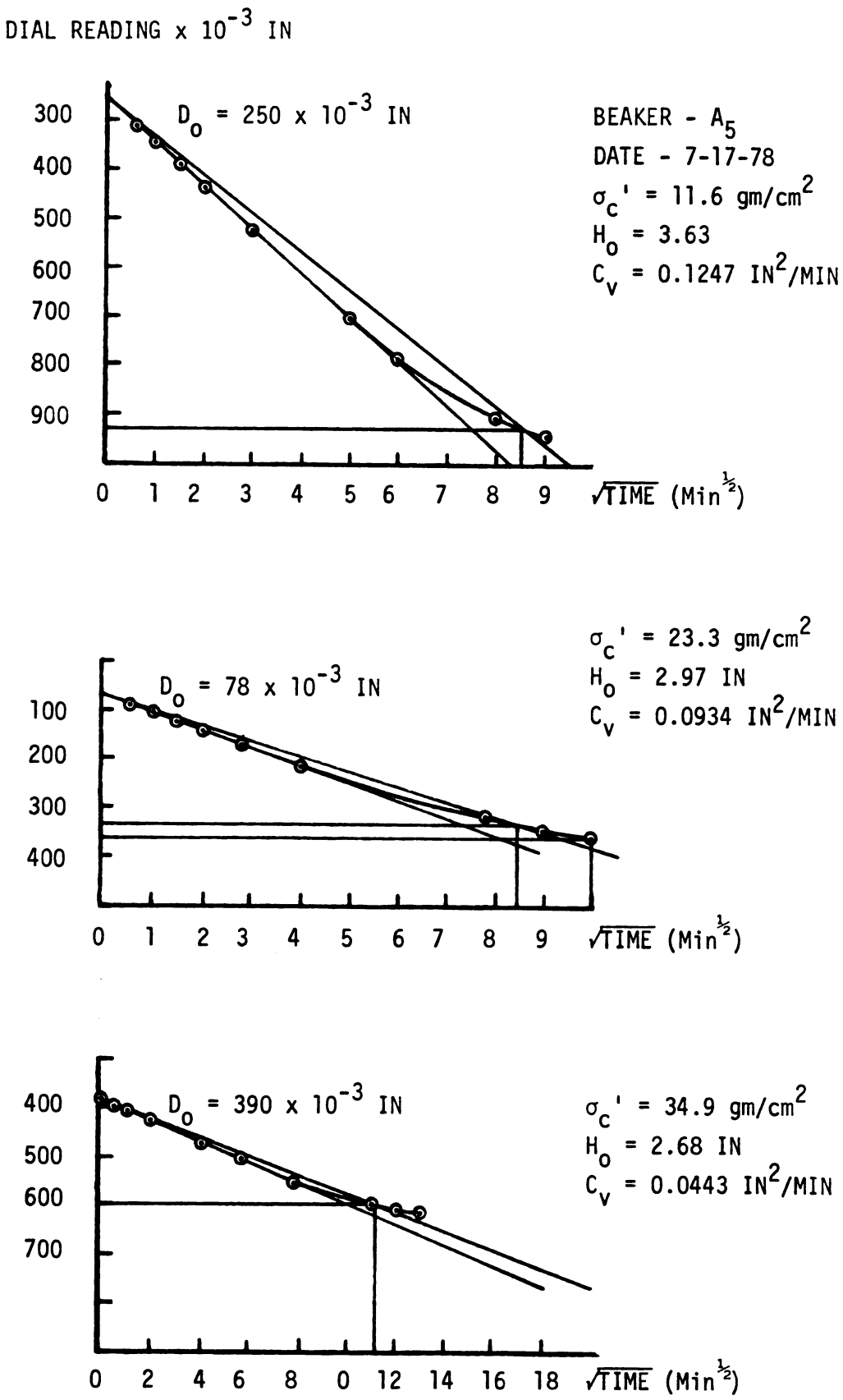

DIAL READING x 10^{-3} IN
300
400
500
600
700
800
900
D_o = 250 x 10^{-3} IN
BEAKER - A_5
DATE - 7-17-78
σ_c' = 11.6 gm/cm^2
H_o = 3.63
C_v = 0.1247 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)
100
200
300
400
D_o = 78 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 2.97 IN
C_v = 0.0934 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)
400
500
600
700
D_o = 390 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 2.68 IN
C_v = 0.0443 IN^2/MIN
0 2 4 6 8 0 12 14 16 18
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-8* Consolidation Data, Anaerobic, Stage III - 2. (Continue 2)

Beaker	B_1
Date	4-19-78
X_{FI} (%)	56.70
X_{CI} (%)	43.30
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	1.89
W_L (gm)	20.95
W_{tl} (gm)	312.50
W_t-W_L(gm)	291.55
X_{DI} (%)	15.02
W_{FI} (gm)	160.50
W_{CI} (gm)	122.57
W_{SI} (gm)	283.07
H_{SI} (cm)	0.87
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.25
e	14.33
X_{WE} (%)	758
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.25
H_f (IN)	4.51
e	12.17
X_{WE}	643
TIME (MIN)	DIAL READING (10^{-3} IN)
0	185
.25	250
.50	276
.75	296
1.0	313
2	368
4	434
8	530
16	659
30	781
60	922
PRESS.	11-6-23.3gm/cm^2
H_i(IN)	4.51
H_f(IN)	3.80
e	10.09
X_{WE}(%)	5.33
TIME (MIN)	DIAL READING (10^{-3} IN)
0	278
.25	360
.50	390
.75	413
1.0	432
2	484
4	563
8	650
16	767
30	870
60	990
PRESS.	23.3-34.9gm/cm^2
H_i(IN)	3.80
H_f(IN)	3.31
e	8.67
X_{WE}(%)	458
TIME (MIN)	DIAL READING (10^{-3} IN)
0	247
.25	282
.50	295
.75	306
1.0	315
2	354
4	400
8	465
16	551
30	642
49	712
60	739
PRESS.	34.9-46.5gm/cm^2
H_i(IN)	3.31
H_f(IN)	2.98
e	7.69
X_{WE}(%)	407
TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
.25	222
.50	230
.75	236
1.0	241
2	259
4	290
8	332
16	387
30	455
60	532
100	582
121	603
144	610
169	623

*Sodium bicarbonate added before consolidation.

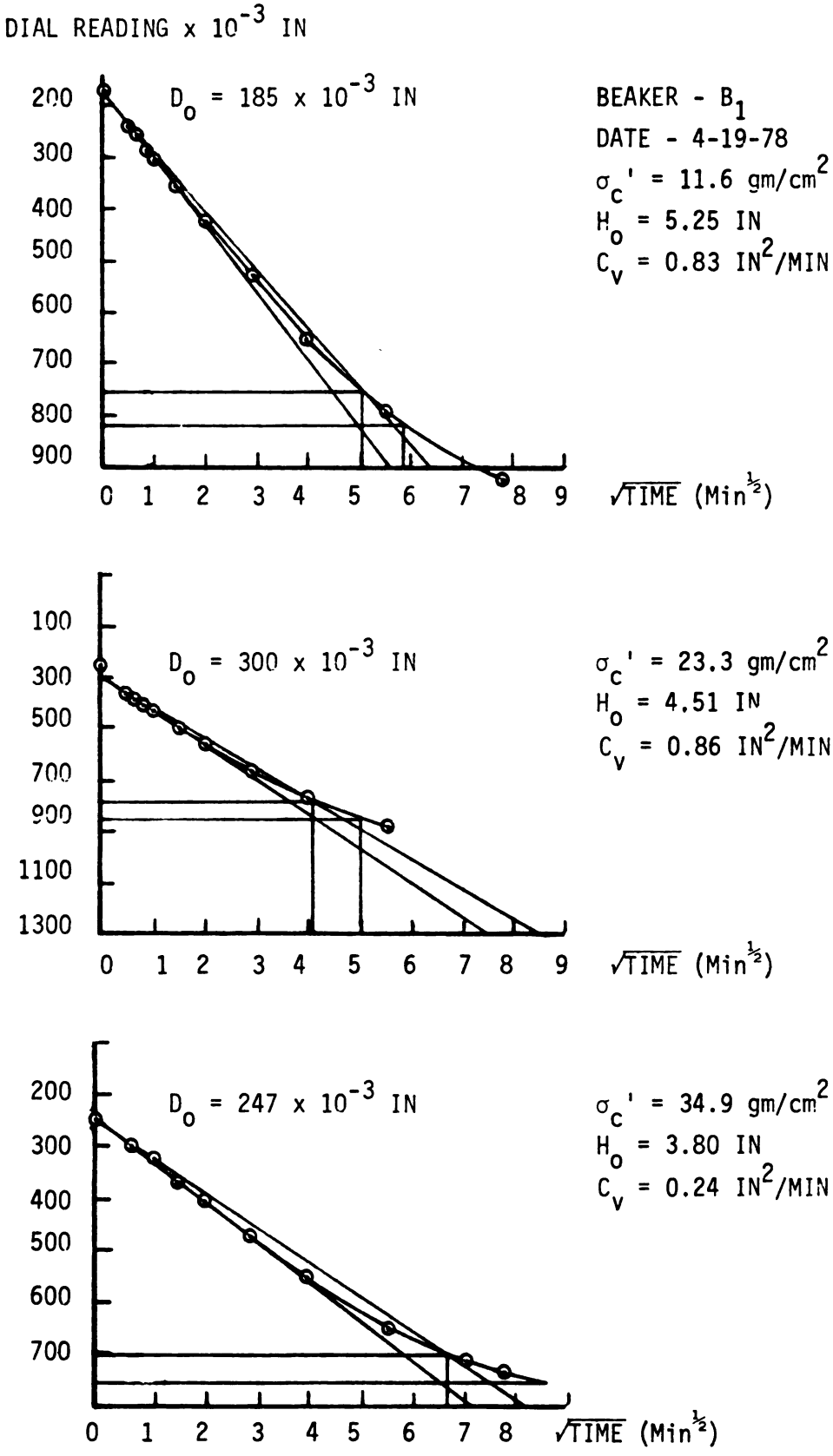

DIAL READING x 10^{-3} IN
200
300
400
500
600
700
800
900
D_o = 185 x 10^{-3} IN
BEAKER - B_1
DATE - 4-19-78
σ_c' = 11.6 gm/cm^2
H_o = 5.25 IN
C_v = 0.83 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
100
300
500
700
900
1100
1300
D_o = 300 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.51 IN
C_v = 0.86 IN^2/MIN
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
200
300
400
500
600
700
D_o = 247 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.80 IN
C_v = 0.24 IN^2/MIN
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-8 Consolidation Data, Anaerobic, Stage III - 2. (Continue 3)

Beaker	B_5
Date	7-18-78
X_{FI} (%)	50.68
X_{CI} (%)	49.32
X_{FO} (%)	61.51
X_{CA} (%)	38.49
G_{SI}	1.95
W_L (gm)	20.10
W_{tl} (gm)	312.50
W_t-W_L(gm)	292.40
X_{DI} (%)	35.70
W_{FI} (gm)	115.65
W_{CI} (gm)	112.54
W_{SI} (gm)	228.19
H_{SI} (cm)	0.68

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	3.75
e	13.01
X_{WE} (%)	667

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i	3.75
H_f	3.40
e	11.71
X_{WE}	600

TIME (MIN)	DIAL READING (10^{-3} IN)
0	290
0.25	340
0.5	357
0.75	371
1	371
2	413
4	460
10	527
16	557
30	594
60	637

PRESS.	11.6-23.3gm/cm^2
H_i(IN)	3.40
H_f(IN)	2.86
e	9.68
X_{WE}(%)	496

TIME (MIN)	DIAL READING (10^{-3} IN)
0	385
0.25	476
0.50	500
0.75	519
1.0	536
2	591
4	663
8	746
16	807
30	868
60	928

PRESS	23.3-34.9gm/cm^2
H_i(IN)	2.86
H_f(IN)	2.54
e	8.49
X_{WE}(%)	435

TIME (MIN)	DIAL READING (10^{-3} IN)
0	290
0.25	320
0.50	331
0.75	340
1.0	347
2	370
5	425
10	474
22	535
36	570
60	612

PRESS.	34.9-46.5gm/cm^2
H_i(IN)	2.54
H_f(IN)	2.27
e	7.49
X_{WE}(%)	384

TIME (MIN)	DIAL READING (10^{-3} IN)
0	365
0.25	387
0.50	394
0.75	400
1.0	405
2	423
8	481
19	531
30	558
60	600
104	632

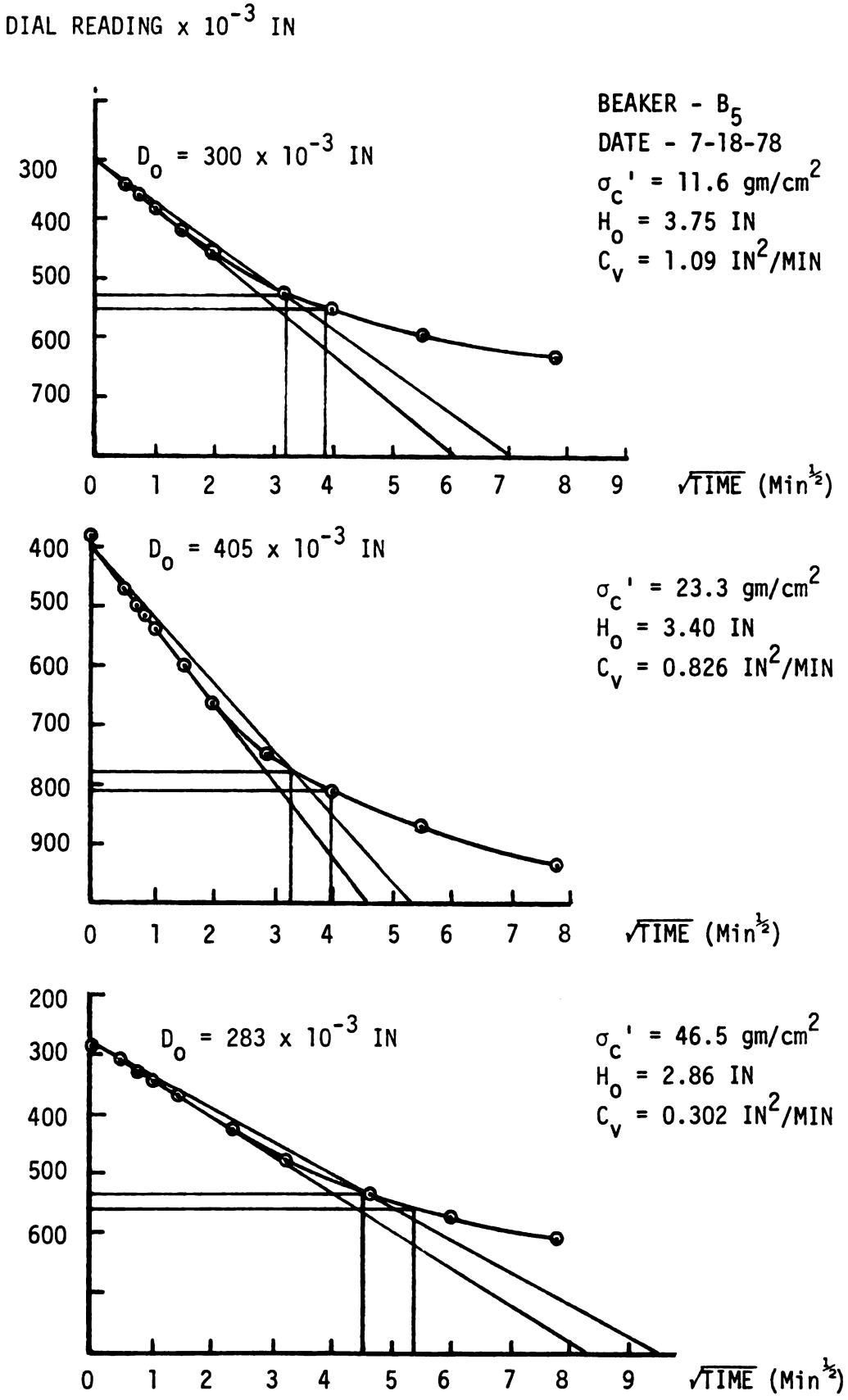

DIAL READING x 10^{-3} IN
BEAKER - B_5
DATE - 7-18-78
D_o = 300 x 10^{-3} IN
σ_c' = 11.6 gm/cm^2
H_o = 3.75 IN
C_v = 1.09 IN^2/MIN
300
400
500
600
700
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)
D_o = 405 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 3.40 IN
C_v = 0.826 IN^2/MIN
400
500
600
700
800
900
0 1 2 3 4 5 6 7 8
$\sqrt{TIME}$ (Min$^{1/2}$)
D_o = 283 x 10^{-3} IN
σ_c' = 46.5 gm/cm^2
H_o = 2.86 IN
C_v = 0.302 IN^2/MIN
200
300
400
500
600
0 1 2 3 4 5 6 7 8 9
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-8* Consoldiation Data, Anaerobic, Stage III - 2. (Continue 4)

Beaker	C_1
Date	4-20-78
X_{FI} (%)	75.98
X_{CI} (%)	24.02
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.72
W_L (gm)	16.4
W_{tl} (gm)	225
W_t-W_L(gm)	208.6
X_{DI} (%)	3.21
W_{FI} (gm)	154.60
W_{CI} (gm)	48.87
W_{SI} (gm)	203.47
H_{SI} (cm)	0.69

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.69
e	19.94
X_{WE} (%)	1163

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	4.65
H_f(IN)	3.44
e	11.67
X_{WE}(%)	681

TIME (MIN)	DIAL READING (10^{-3} IN)
0	12
.25	126
.5	163
.75	189
1	215
2	312
4	427
9	654
16	836
30	1020
69	1219

PRESS.	23.3-34.9gm/cm^2
H_i(IN)	3.44
H_f(IN)	2.93
e	11.67
X_{WE}(%)	681

TIME (MIN)	DIAL READING (10^{-3} IN)
0	40
.25	88
.50	--
.75	117
1.0	128
2	164
4	215
8	282
16	372
30	461
49	525
60	550

PRESS.	34.9-46.5gm/cm^2
H_i(IN)	2.93
H_f(IN)	2.60
e	8.57
X_{WE}(%)	500

TIME (MIN)	DIAL READING (10^{-3} IN)
.25	314
.50	334
.75	351
1.0	356
2	375
4	403
8	442
16	503
30	568
49	614
137	705
176	724
212	737

*Sodium bicarbonate added before consolidation.

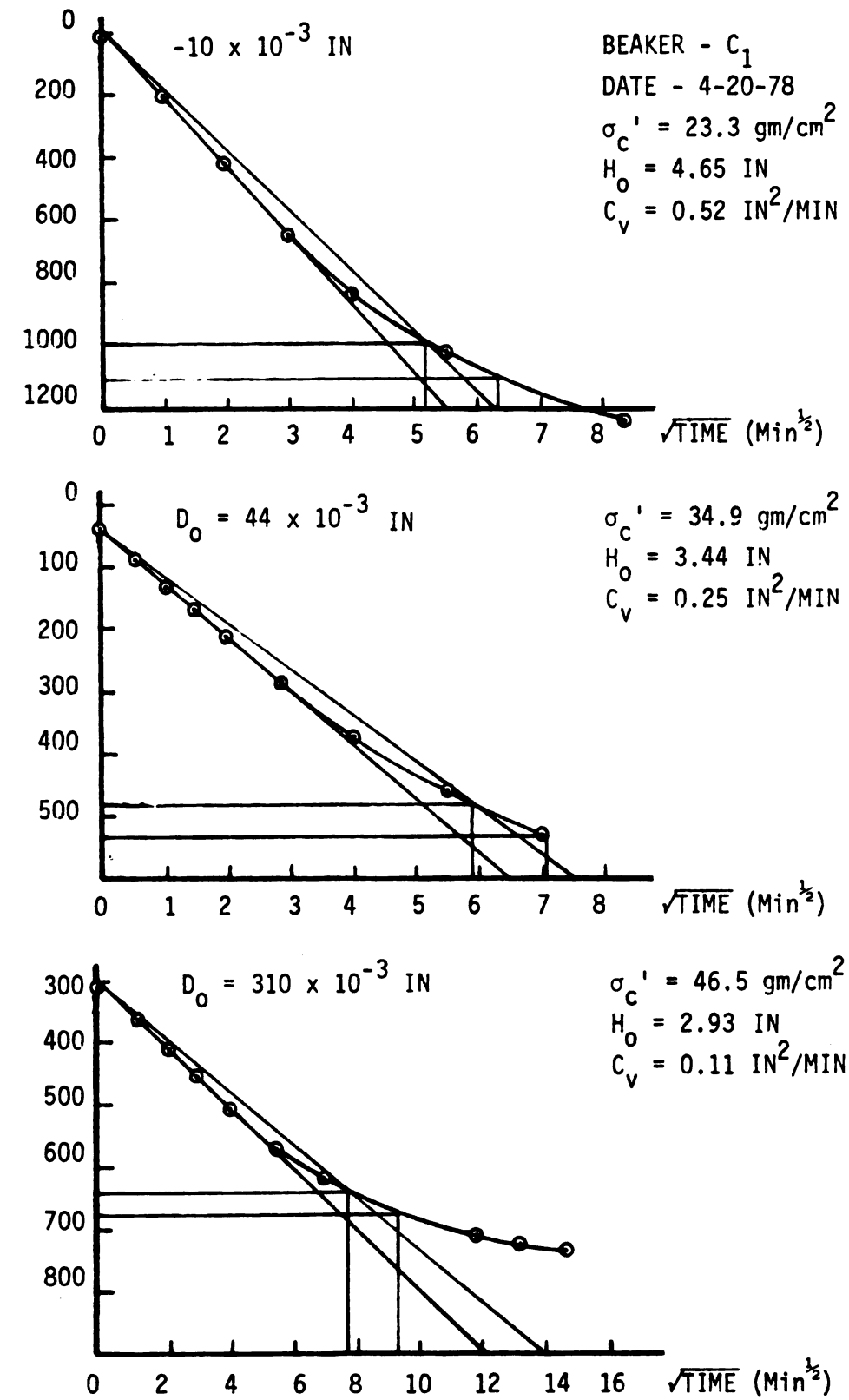
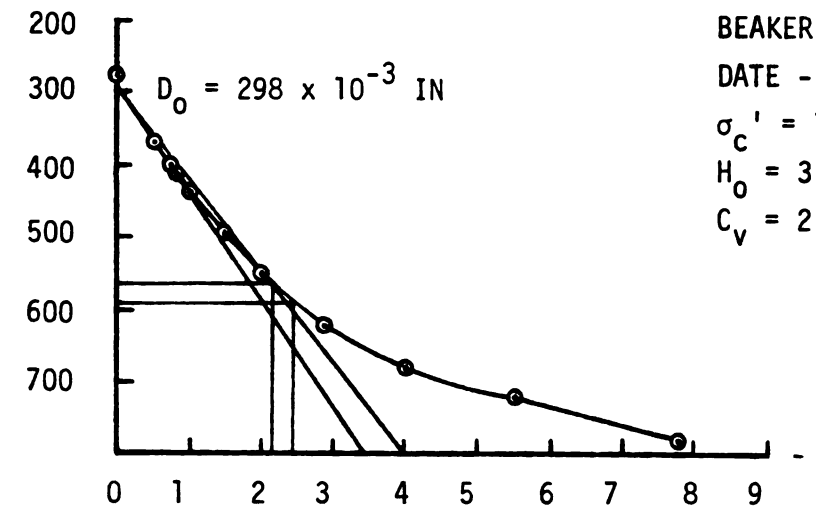

DIAL READING x 10^{-3} IN
-10 x 10^{-3} IN
BEAKER - C_1
DATE - 4-20-78
σ_c' = 23.3 gm/cm^2
H_o = 4.65 IN
C_v = 0.52 IN^2/MIN
D_o = 44 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.44 IN
C_v = 0.25 IN^2/MIN
D_o = 310 x 10^{-3} IN
σ_c' = 46.5 gm/cm^2
H_o = 2.93 IN
C_v = 0.11 IN^2/MIN
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-8 Consolidation Data, Anaerobic, Stage III - 2. (Continue 5)

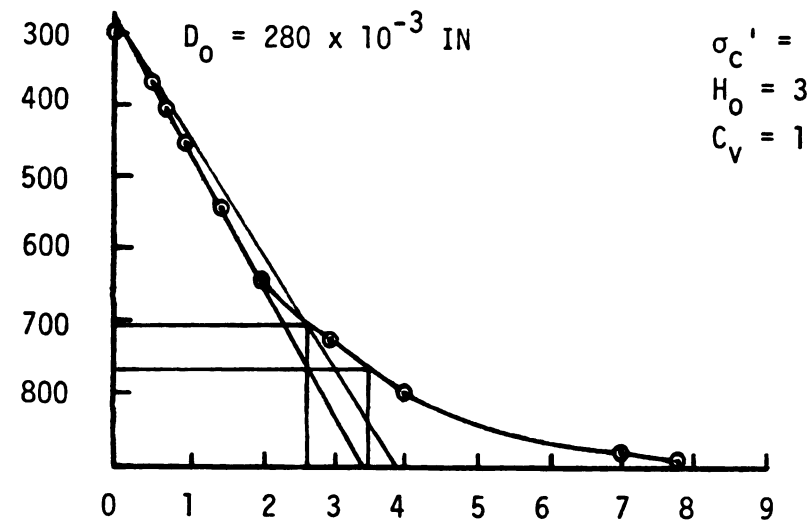
Beaker	C_5
Date	7-19-78
X_{FI} (%)	74.88
X_{CI} (%)	25.12
X_{FO} (%)	81.87
X_{CA} (%)	18.13
G_{SI}	1.73
W_L (gm)	18.90
W_{tl} (gm)	225
W_t-W_L(gm)	206.10
X_{DI} (%)	34.00
W_{FI} (gm)	111.36
W_{CI} (gm)	37.37
W_{SI} (gm)	148.73
H_{SI} (cm)	0.50
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	3.81
e	18.36
X_{WE} (%)	1062
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i(IN)	3.81
H_f(IN)	3.31
e	15.82
X_{WE}	915
TIME (MIN)	DIAL READING (10^{-3} IN)
0	280
0.25	370
0.50	400
0.75	422
1.0	441
2	493
4	562
8	623
16	677
30	720
60	784
PRESS	11.6-23.3gm/cm^2
H_i(IN)	3.31
H_f(IN)	2.71
e	12.76
X_{WE}(%)	738
TIME (MIN)	DIAL READING (10^{-3} IN)
0	300
0.25	375
0.50	408
0.75	440
2	545
4	649
8	727
16	802
49	884
60	893
PRESS	23.3-34.9gm/cm^2
H_i(IN)	2.71
H_f(IN)	2.36
e	10.98
X_{WE}(%)	635
TIME (MIN)	DIAL READING (10^{-3} IN)
0	237
0.25	278
0.50	---
0.75	304
1.0	315
2	364
4	409
8	455
16	496
36	544
70	586
PRESS	34.9-46.5gm/cm^2
H_i(IN)	2.36
H_f(IN)	2.17
e	10.00
X_{WE}(%)	578
TIME (MIN)	DIAL READING (10^{-3} IN)
0	315
0.50	346
0.75	353
1.0	358
3	391
4	400
9	433
16	456
30	481
60	510
100	535
169	564

DIAL READING x 10^{-3} IN



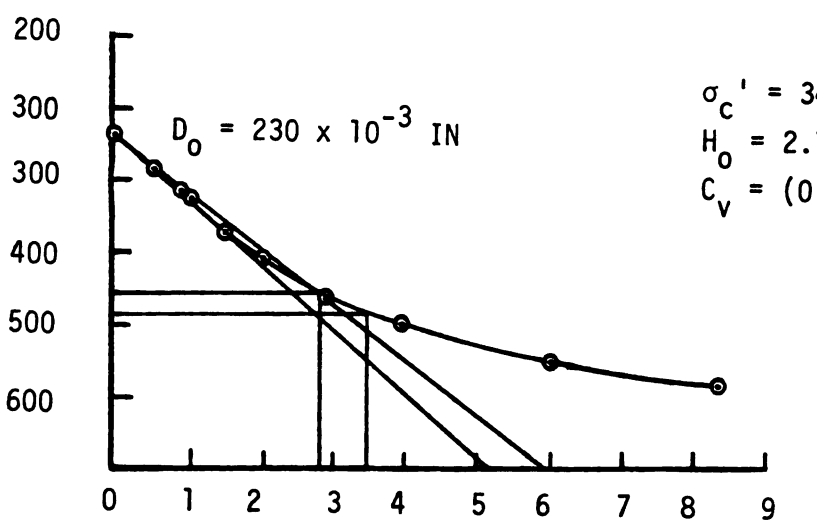
D_o = 298 x 10^{-3} IN

BEAKER - C_5
DATE - 7-19-78
σ_c' = 11.6 gm/cm^2
H_o = 3.81 IN
C_v = 2.58 IN^2/MIN



D_o = 280 x 10^{-3} IN

σ_c' = 23.3 gm/cm^2
H_o = 3.31 IN
C_v = 1.09 IN^2/MIN



D_o = 230 x 10^{-3} IN

σ_c' = 34.9 gm/cm^2
H_o = 2.71 IN
C_v = (0.848)(2.59)^2 = 0.7244 IN^2/MIN

TABLE B-9 Consolidation Data, Anaerobic, Stage III - 3

Beaker	A_2
Date	4-25-78
X_{FI} (%)	22.95
X_{CI} (%)	77.05
X_{FO} (%)	30.71
X_{CA} (%)	69.29
G_{SI}	2.30
W_L (gm)	0
W_{tl} (gm)	500
W_t-W_L(gm)	500
X_{DI} (%)	32.80
W_{FI} (gm)	103.19
W_{CI} (gm)	346.45
W_{SI} (gm)	449.64
H_{SI} (cm)	1.14
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.12
e	10.40
X_{WE} (%)	454
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i (IN)	5.12
H_f (IN)	4.93
e	9.97
X_{WE}(%)	435
TIME (MIN)	DIAL READING (10^{-3} IN)
0	105
.25	---
.50	---
.75	---
1.0	149
2	156
4	165
8	187
16	213
30	238
49	263
60	275
116	326
180	372
240	400
PRESS.	11.6-23.3gm/cm^2
H_i(IN)	4.93
H_f(IN)	4.65
e	9.36
X_{WE}(%)	408
TIME (MIN)	DIAL READING (10^{-3} IN)
0	310
.25	342
.50	347
.75	351
1.0	354
2	---
4	373
8	384
16	400
30	418
60	447
100	468
144	477
700	535
PRESS.	23.3-34.9gm/cm^2
H_i(IN)	4.65
H_f(IN)	4.48
e	8.97
X_{WE}(%)	3.91
TIME (MIN)	DIAL READING (10^{-3} IN)
0	50
.25	--
.50	83
.75	86
1.0	88
2	93
4	98
8	105
16	111
30	124
60	135
127	148
169	159
256	170
400	185

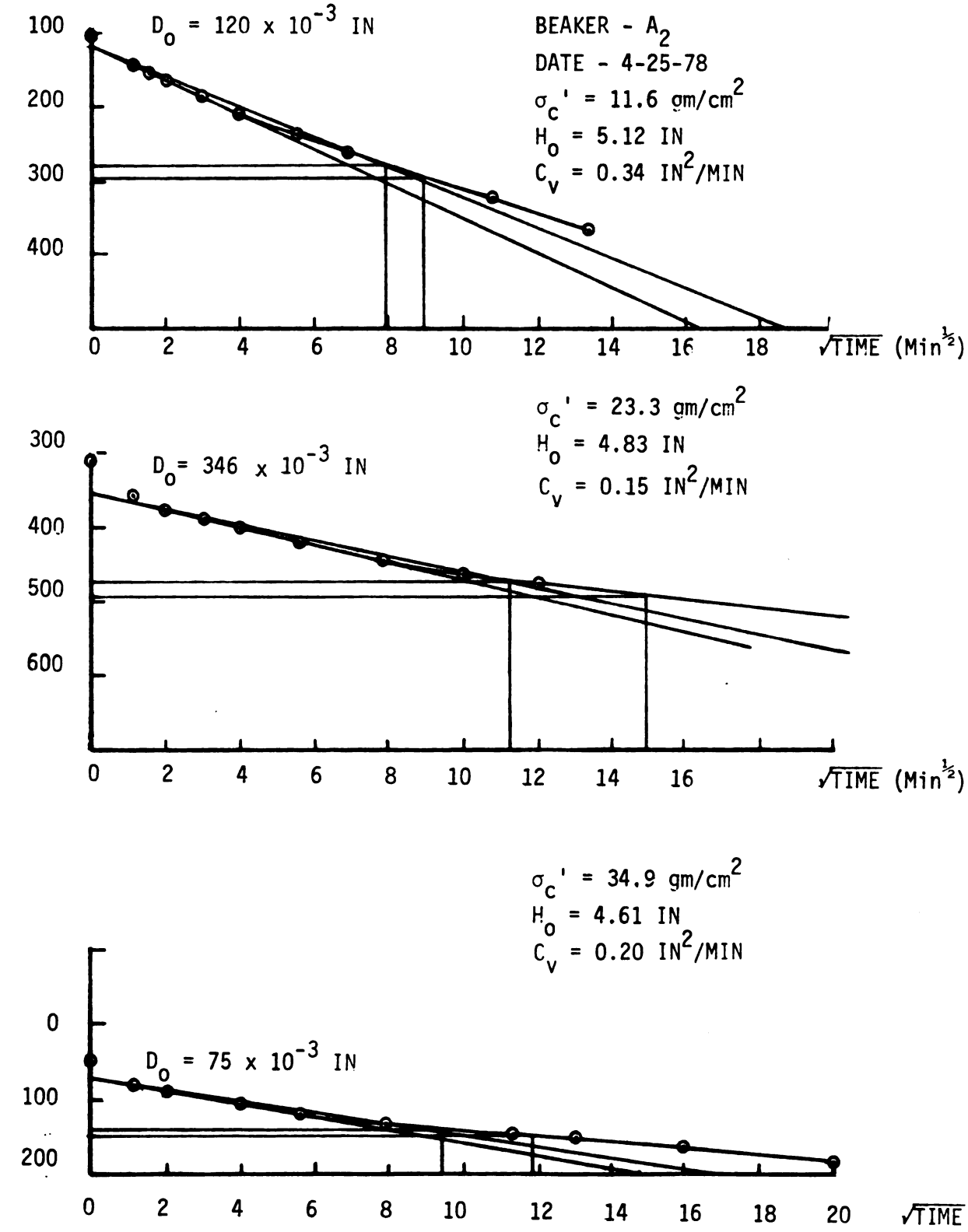

DIAL READING x 10^{-3} IN
D_o = 120 x 10^{-3} IN
BEAKER - A_2
DATE - 4-25-78
σ_c' = 11.6 gm/cm^2
H_o = 5.12 IN
C_v = 0.34 IN^2/MIN
100
200
300
400
0 2 4 6 8 10 12 14 16 18
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
σ_c' = 23.3 gm/cm^2
H_o = 4.83 IN
C_v = 0.15 IN^2/MIN
D_o = 346 x 10^{-3} IN
300
400
500
600
0 2 4 6 8 10 12 14 16
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
σ_c' = 34.9 gm/cm^2
H_o = 4.61 IN
C_v = 0.20 IN^2/MIN
D_o = 75 x 10^{-3} IN
0
100
200
0 2 4 6 8 10 12 14 16 18 20
$\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-9 Consolidation Data, Anaerobic, Stage III - 3. (Continue 2)

Beaker	B_2
Date	4-26-78
X_{FI} (%)	49.69
X_{CI} (%)	50.31
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	1.96
W_L (gm)	0
W_{tl} (gm)	312.5
W_t-W_L(gm)	312.5
X_{DI} (%)	28.36
W_{FI} (gm)	129.76
W_{CI} (gm)	131.38
W_{SI} (gm)	261.14
H_{SI} (cm)	0.77

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.94
e	15.30
X_{WE} (%)	776

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	4.94
H_f(IN)	4.17
e	12.77
X_{WE}	648

TIME (MIN)	DIAL READING (10^{-3} IN)
0	170
.25	211
.50	226
.75	237
1.0	247
2	276
4	316
8	371
16	446
30	541
49	636
60	680
81	747
100	795
125	843
169	895
256	950

PRESS	11.6-23.3gm/cm^2
H_i(IN)	4.17
H_f(IN)	3.72
e	11.27
X_{WE}(%)	572

TIME (MIN)	DIAL READING (10^{-3} IN)
0	68
.25	--
.50	117
.75	---
1.0	
2	163
4	198
8	246
16	307
30	386
49	451
60	478
	530

PRESS	23.3-34.9gm/cm^2
H_i(IN)	3.72
H_f(IN)	3.23
e	9.66
X_{WE}(%)	490

TIME (MIN)	DIAL READING (10^{-3} IN)
0	280
.5	318
2	344
4	370
8	407
16	458
36	541
60	605
81	648
144	726
196	760

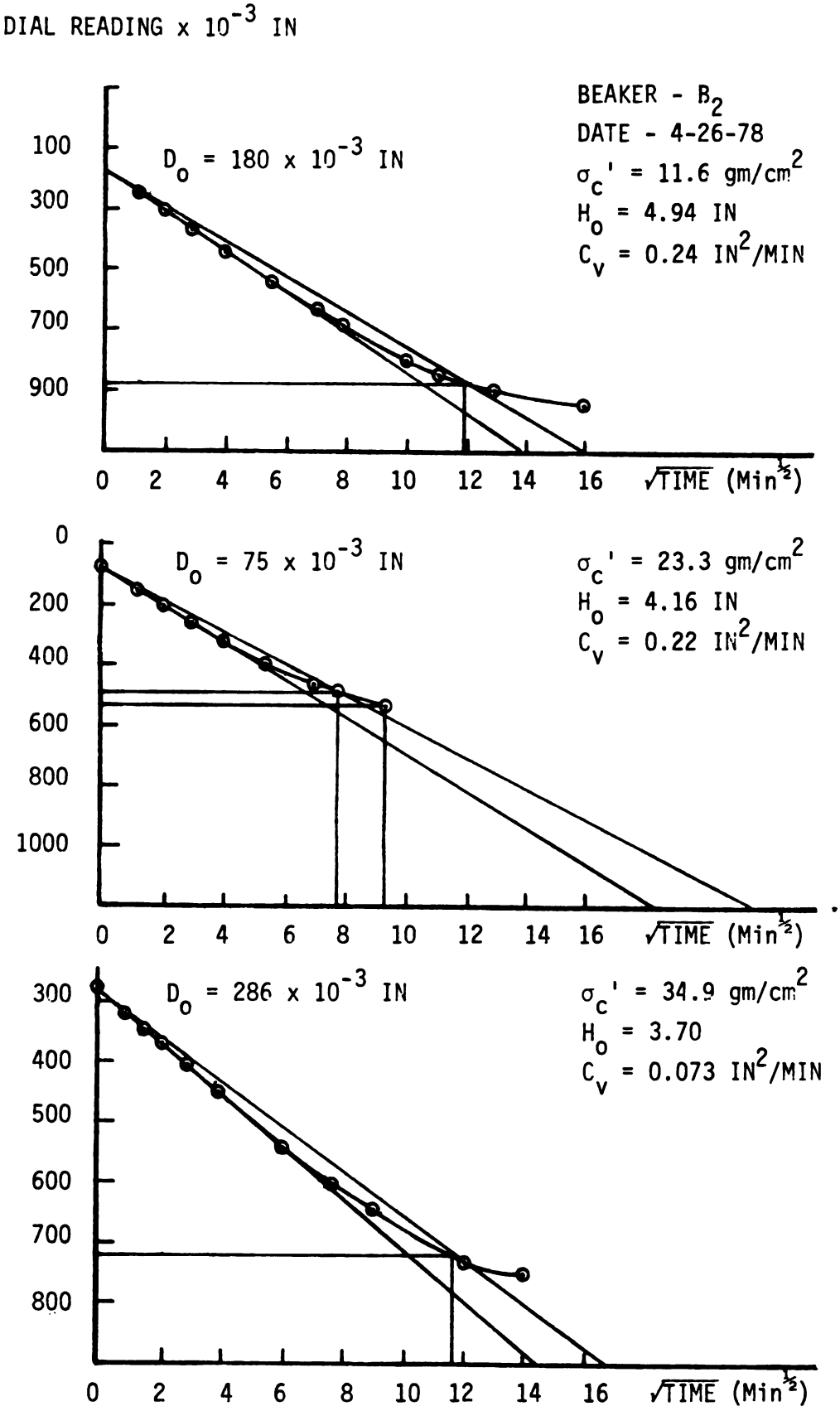

DIAL READING x 10^{-3} IN
BEAKER - B_2
DATE - 4-26-78
D_o = 180 x 10^{-3} IN
σ_c' = 11.6 gm/cm^2
H_o = 4.94 IN
C_v = 0.24 IN^2/MIN
100
300
500
700
900
0 2 4 6 8 10 12 14 16 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
D_o = 75 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 4.16 IN
C_v = 0.22 IN^2/MIN
0
200
400
600
800
1000
0 2 4 6 8 10 12 14 16 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
D_o = 286 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 3.70
C_v = 0.073 IN^2/MIN
300
400
500
600
700
800
0 2 4 6 8 10 12 14 16 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-9 Consolidation Data, Anaerobic, Stage III - 3. (Continue 4)

Beaker	C_2
Date	4-27-78
X_{FI} (%)	70.78
X_{CI} (%)	29.22
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.76
W_L (gm)	0
W_{tl} (gm)	225
$W_t - W_L$ (gm)	225
X_{DI} (%)	25.88
W_{FI} (gm)	127.70
W_{CI} (gm)	57.72
W_{SI} (gm)	180.42
H_{SI} (cm)	0.62

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	5.00
e	20.17
X_{WE} (%)	1154

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i (IN)	4.38
H_f (IN)	3.25
e	12.75
X_{WE} (%)	729

TIME (MIN)	DIAL READING (10^{-3} IN)
0	31
.25	64
.50	76
.75	85
1.0	93
2	119
4	152
8	210
16	302
30	422
60	617
81	715
144	905
169	948
196	993
256	1060

PRESS	23.3-34.9gm/cm^2
H_i (IN)	3.25
H_f (IN)	2.36
e	8.98
X_{WE} (%)	514

TIME (MIN)	DIAL READING (10^{-3} IN)
0	0
1.0	45
4	90
16	178
64	350
144	520
196	611
256	683
324	742
400	784

PRESS	34.9-46.5gm/cm^2
H_i (IN)	2.36
H_f (IN)	1.83
e	6.75
X_{WE} (%)	386

TIME (MIN)	DIAL READING (10^{-3} IN)
0	145
.75	---
1.0	175
4	185
16	208
36	260
64	311
121	389
196	462
256	500
639	607
774	678

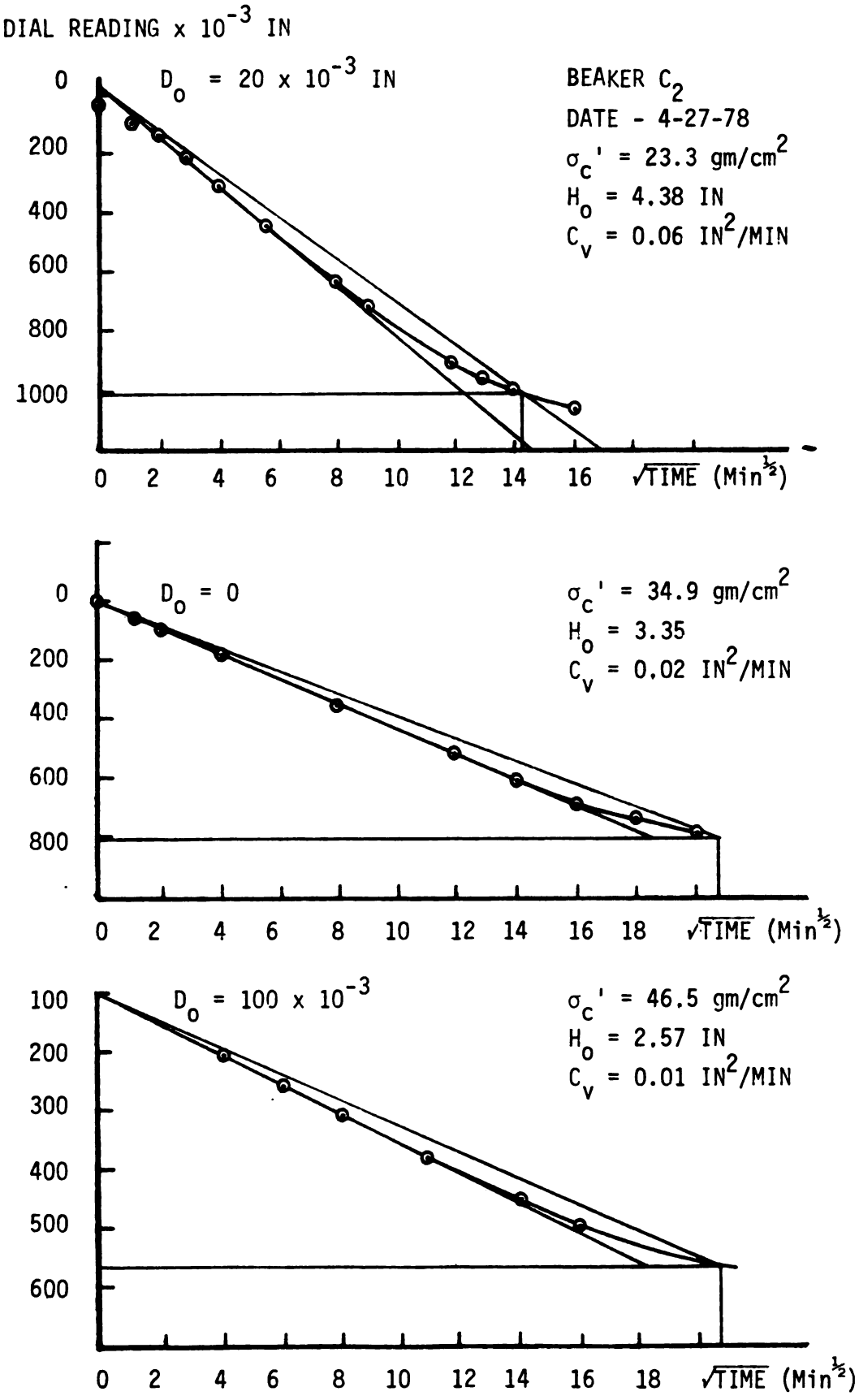

DIAL READING x 10^{-3} IN
D_o = 20 x 10^{-3} IN
BEAKER C_2
DATE - 4-27-78
σ_c' = 23.3 gm/cm^2
H_o = 4.38 IN
C_v = 0.06 IN^2/MIN
0
200
400
600
800
1000
0 2 4 6 8 10 12 14 16 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
D_o = 0
σ_c' = 34.9 gm/cm^2
H_o = 3.35
C_v = 0.02 IN^2/MIN
0
200
400
600
800
0 2 4 6 8 10 12 14 16 18 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)
D_o = 100 x 10^{-3}
σ_c' = 46.5 gm/cm^2
H_o = 2.57 IN
C_v = 0.01 IN^2/MIN
100
200
300
400
500
600
0 2 4 6 8 10 12 14 16 18 $\sqrt{TIME}$ (Min$^{\frac{1}{2}}$)

TABLE B-10 Consolidation Data, Anaerobic, Stage III - 5

Beaker	A_4
Date	5-9-78
X_{FI} (%)	21.03
X_{CI} (%)	78.98
X_{FO} (%)	30.71
X_{CA} (%)	69.29
G_{SI}	2.33
W_L (gm)	0
W_{tl} (gm)	500
$W_t - W_L$ (gm)	500
X_{DI} (%)	39.91
W_{FI} (gm)	92.27
W_{CI} (gm)	346.45
W_{SI} (gm)	438.72
H_{SI} (cm)	1.09

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	4.15
e	8.67
X_{WE} (%)	370

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	4.15
H_f(IN)	3.93
e	8.15
X_{WE}(%)	348

TIME (MIN)	DIAL READING (10^{-3} IN)
0	120
0.25	130
0.75	134
1.0	136
2	140
4	145
8	153
16	164
30	182
60	206
105	229
169	259
225	280
256	289
315	305
400	325
506	335
625	345

PRESS	11.63-23.26gm/cm^2
H_i(IN)	3.93
H_f(IN)	3.73
e	7.70
X_{WE}(%)	329

TIME (MIN)	DIAL READING (10^{-3} IN)
0	510
1.0	526
4	534
9	542
16	550
64	579
100	592
225	625
400	655
625	685
900	708

PRESS	23.26-34.88gm/cm^2
H_i(IN)	3.73
H_f(IN)	3.57
e	10.16
X_{WE}(%)	562

TIME (MIN)	DIAL READING (10^{-3} IN)
0	479
4	502
16	509
36	521
81	542
144	568
196	585
256	598
400	616
650	629

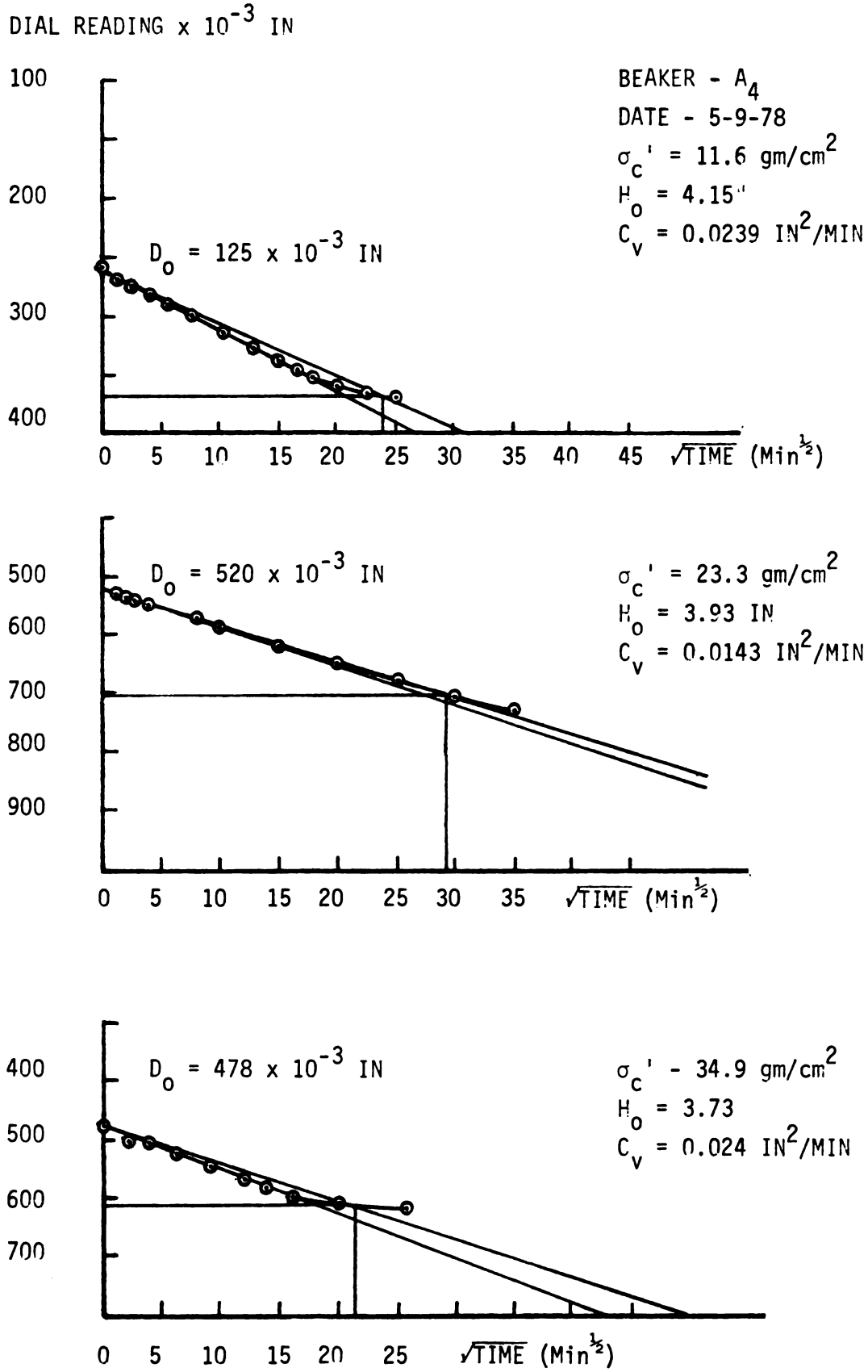

DIAL READING x 10^{-3} IN
100
200
300
400
D_o = 125 x 10^{-3} IN
BEAKER - A_4
DATE - 5-9-78
σ_c' = 11.6 gm/cm^2
H_o = 4.15"
C_v = 0.0239 IN^2/MIN
0 5 10 15 20 25 30 35 40 45 $\sqrt{TIME}$ (Min$^{1/2}$)
500
600
700
800
900
D_o = 520 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 3.93 IN
C_v = 0.0143 IN^2/MIN
0 5 10 15 20 25 30 35 $\sqrt{TIME}$ (Min$^{1/2}$)
400
500
600
700
D_o = 478 x 10^{-3} IN
σ_c' - 34.9 gm/cm^2
H_o = 3.73
C_v = 0.024 IN^2/MIN
0 5 10 15 20 25 $\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-10 Consolidation Data, Anaerobic, Stage III - 5. (Continue 1)

Beaker	B_1
Date	5-10-78
X_{FI} (%)	46.00
X_{CI} (%)	54.00
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	2.01
W_L (gm)	50.29
W_{tl} (gm)	312.5
W_t-W_L(gm)	262.21
X_{DI} (%)	38.26
W_{FI} (gm)	77.39
W_{CI} (gm)	110.23
W_{SI} (gm)	187.62
H_{SI} (cm)	0.54

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	3.13
e	13.72
X_{WE} (%)	679

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i	3.13
H_f	2.26
e	9.65
X_{WE}	478

TIME (MIN)	DIAL READING (10^{-3} IN)
0	280
1.0	323
4	365
8	400
16	446
30	502
64	603
144	763
178	818
269	940
324	980
400	1024
529	1076
625	1097
900	1154

PRESS	11.63-23.26gm/cm^2
H_i(IN)	2.26
H_f(IN)	2.01
e	8.46
X_{WE}(%)	419

TIME (MIN)	DIAL READING (10^{-3} IN)
0	278
4	320
9	338
16	356
36	394
64	429
100	467
171	501
221	515
400	540

PRESS	23.26-34.88gm/cm^2
H_i(IN)	2.01
H_f(IN)	1.87
e	7.78
X_{WE}(%)	3.85

TIME (MIN)	DIAL READING (10^{-3} IN)
0	250
1.0	270
4	282
9	292
16	301
36	322
64	342
121	371
169	381
225	391
324	400

DIAL READING x 10^{-3} IN

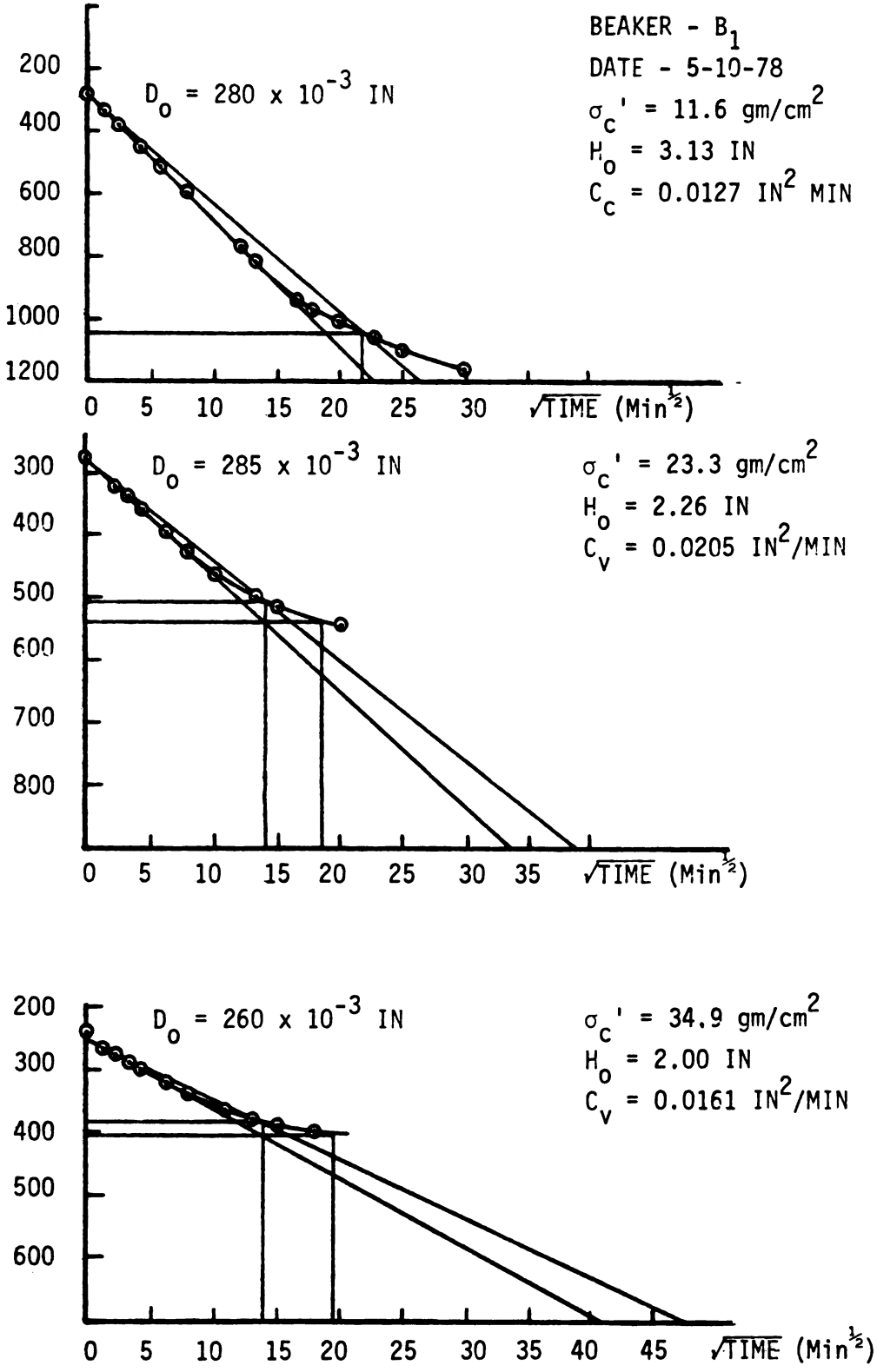


TABLE B-10 Consolidation Data, Anaerobic, Stage III - 5. (Continue 2)

Beaker	C_4
Date	5-11-78
X_{FI} (%)	65.38
X_{CI} (%)	34.62
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.81
W_L (gm)	0
W_{tl} (gm)	225
W_t-W_L(gm)	225
X_{DI} (%)	42.21
W_{FI} (gm)	99.56
W_{CI} (gm)	52.72
W_{SI} (gm)	152.28
H_{SI} (cm)	0.49

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	3.00
e	14.55
X_{WE} (%)	805

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i(IN)	3.00
H_f(IN)	2.54
e	12.18
X_{WE}(%)	674

TIME (MIN)	DIAL READING (10^{-3} IN)
0	200
4	305
9	356
16	400
36	486
64	574
361	700
422	703

PRESS.	11.63-23.26gm/cm^2
H_i(IN)	2.54
H_f(IN)	2.35
e	11.20
X_{WE}(%)	620

TIME (MIN)	DIAL READING (10^{-3} IN)
4	327
9	344
16	360
36	393.5
64	424
100	447
196	477
256	488

PRESS.	23.26-34.88gm/cm^2
H_i(IN)	2.35
H_f(IN)	2.15
e	10.16
X_{WE}(%)	5.62

TIME (MIN)	DIAL READING (10^{-3} IN)
0	473
1.0	502
4	512
9	522
16	535
60	590
100	628
169	650
289	670
400	680

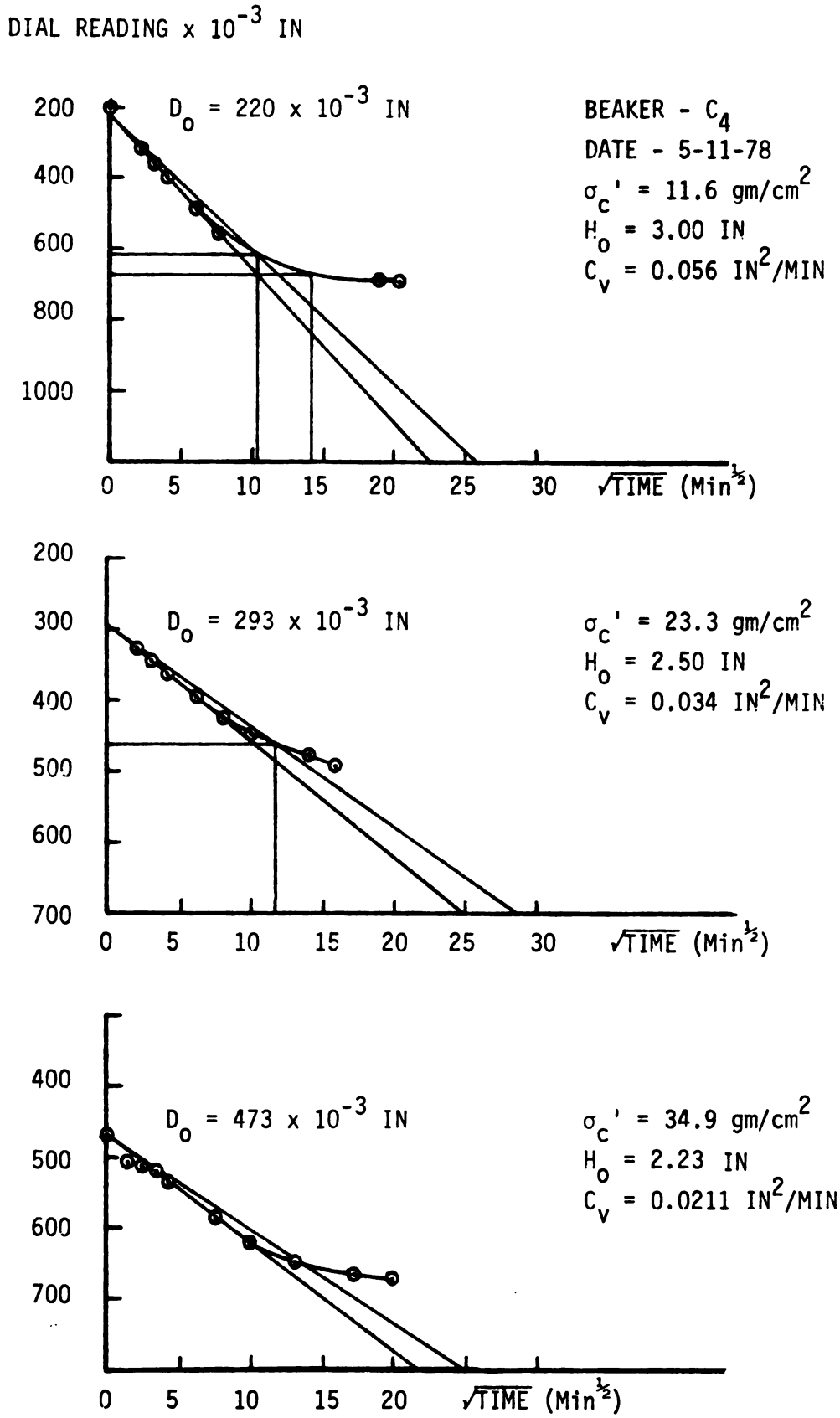

DIAL READING x 10^{-3} IN
200
400
600
800
1000
D_o = 220 x 10^{-3} IN
BEAKER - C_4
DATE - 5-11-78
σ_c' = 11.6 gm/cm^2
H_o = 3.00 IN
C_v = 0.056 IN^2/MIN
0 5 10 15 20 25 30
$\sqrt{TIME}$ (Min$^{1/2}$)
200
300
400
500
600
700
D_o = 293 x 10^{-3} IN
σ_c' = 23.3 gm/cm^2
H_o = 2.50 IN
C_v = 0.034 IN^2/MIN
0 5 10 15 20 25 30
$\sqrt{TIME}$ (Min$^{1/2}$)
400
500
600
700
D_o = 473 x 10^{-3} IN
σ_c' = 34.9 gm/cm^2
H_o = 2.23 IN
C_v = 0.0211 IN^2/MIN
0 5 10 15 20
$\sqrt{TIME}$ (Min$^{1/2}$)

TABLE B-11 Consolidation Data, Anaerobic, Stage III - 7

Beaker	B_4
Date	5-24-78
X_{FI} (%)	40.16
X_{CI} (%)	59.84
X_{FO} (%)	57.96
X_{CA} (%)	42.04
G_{SI}	2.07
W_L (gm)	0
W_{tl} (gm)	312.50
$W_t - W_L$ (gm)	312.50
X_{DI} (%)	51.4
W_{FI} (gm)	88.03
W_{CI} (gm)	131.38
W_{SI} (gm)	219.41
H_{SI} (cm)	0.62

PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	2.16
e	7.81
X_{WE} (%)	380

TIME	DIAL READING
OMITTED	

PRESS	5.8-11.6gm/cm^2
H_i	2.16
H_f	1.99
e	7.16
X_{WE}	348

TIME (MIN)	DIAL READING (10^{-3} IN)
0	391
4	413
9	431
16	448
36	477
64	500
154	537

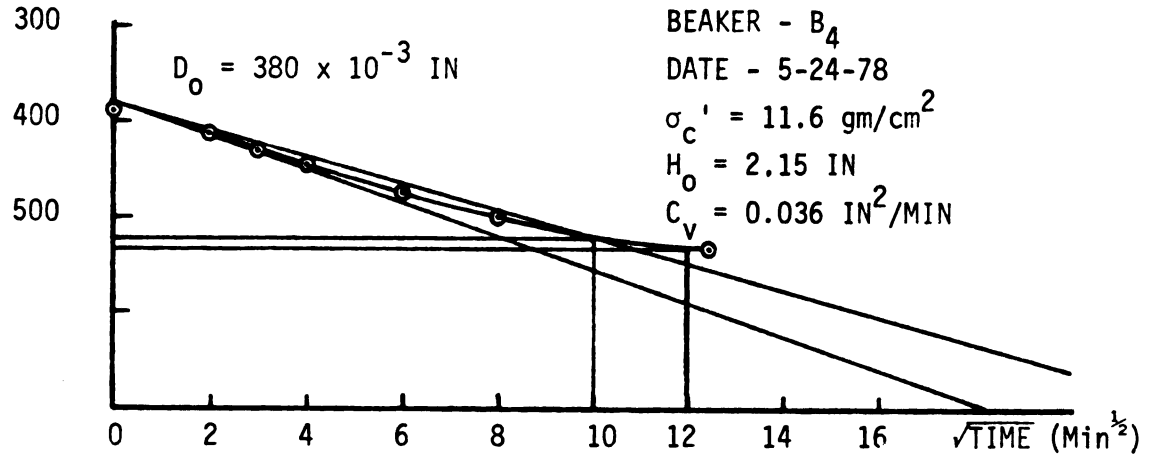
PRESS	11.63-23.26gm/cm^2
H_i (IN)	1.99
H_f (IN)	1.88
e	6.69
X_{WE} (%)	325

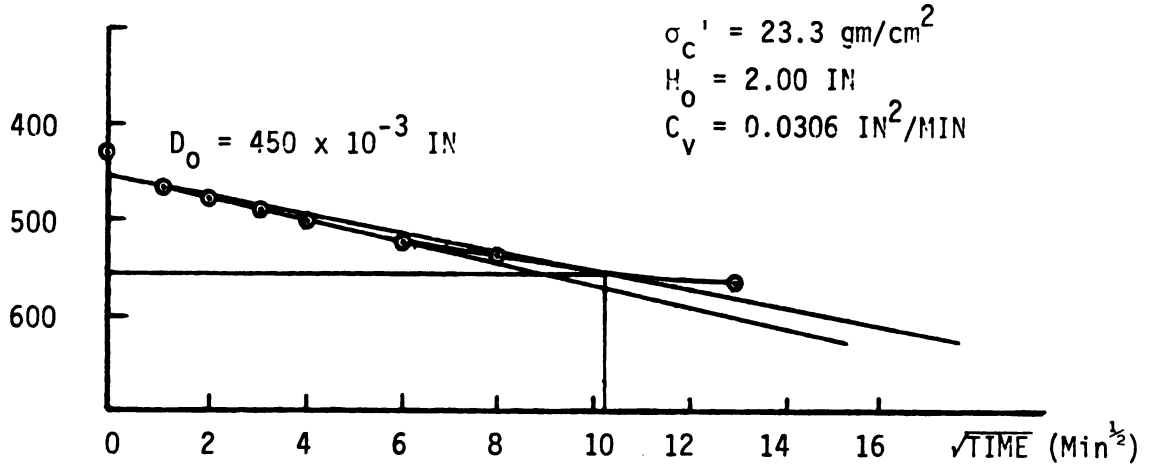
TIME (MIN)	DIAL READING (10^{-3} IN)
0	430
1.0	463
4	474
9	487
16	499
36	520
64	537
169	558

PRESS	23.26-46.51gm/cm^2
H_i (IN)	1.88
H_f (IN)	1.67
e	5.84
X_{WE} (%)	266

TIME	DIAL READING (10^{-3} IN)
0	260
1	286
4	302
9	324
16	342
36	379
81	420
144	470

DIAL READING x 10^{-3} IN





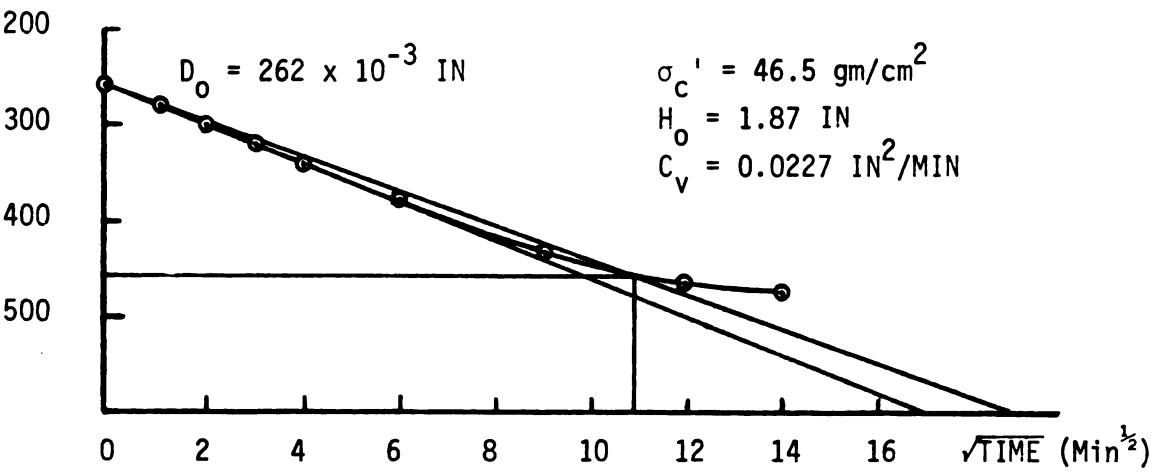
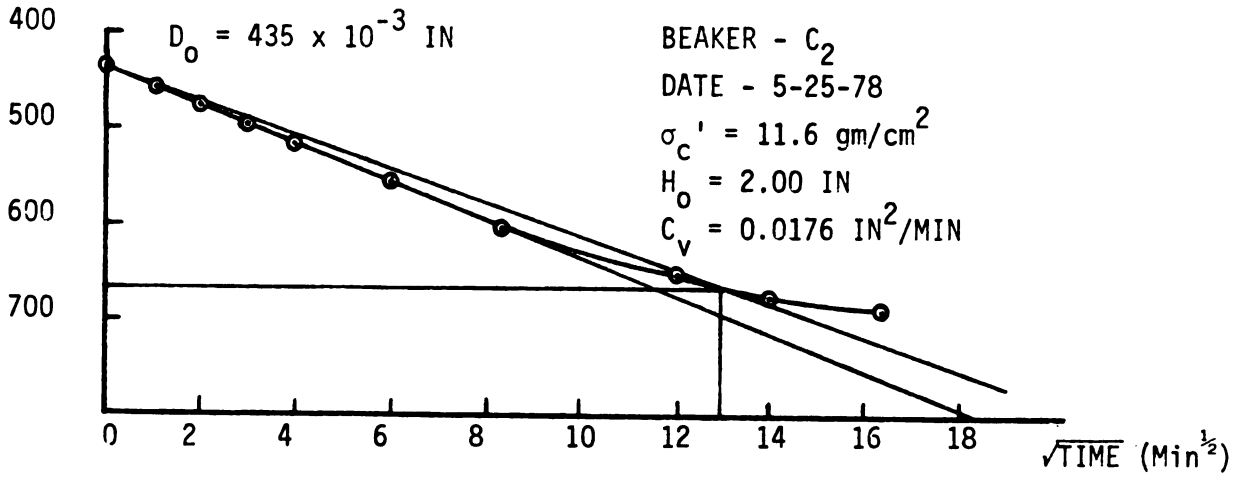
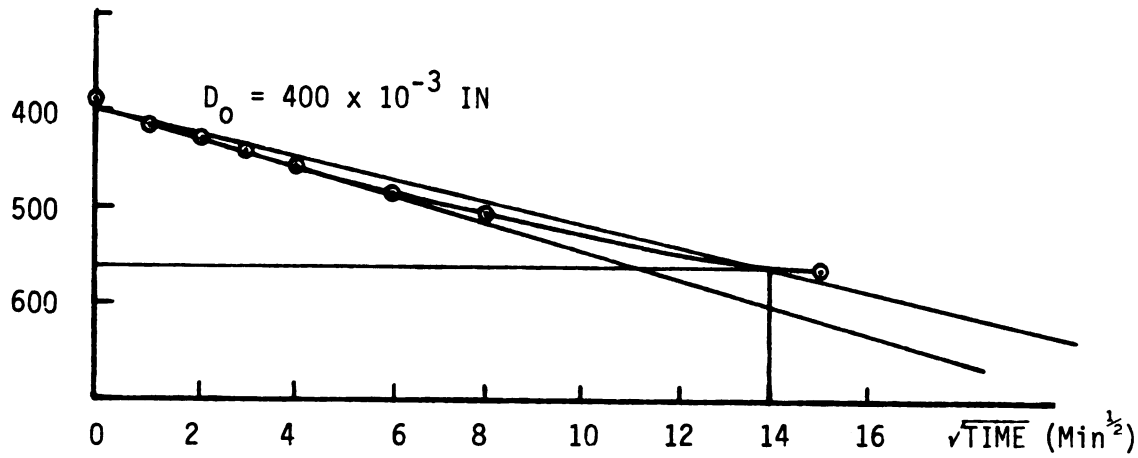


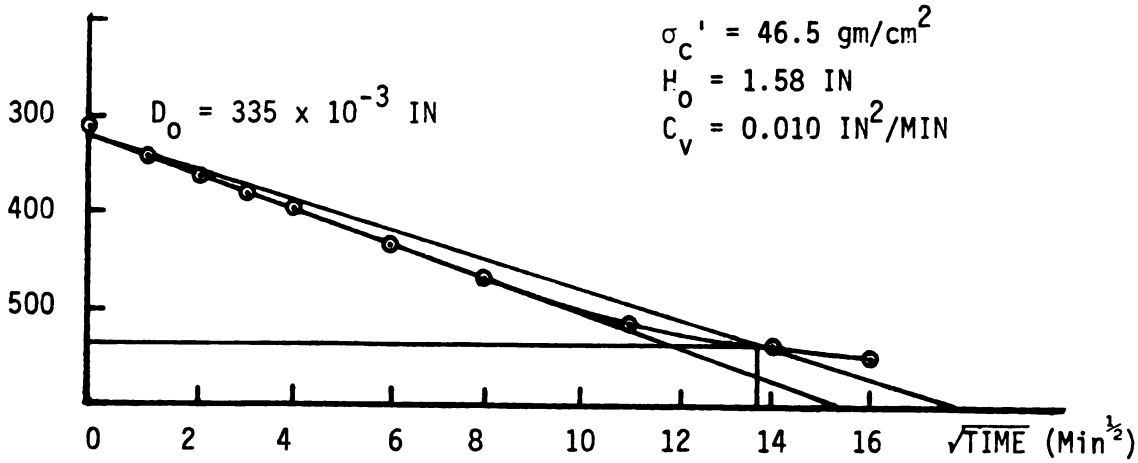
TABLE B-11 Consolidation Data, Anaerobic, Stage III - 7. (Continue 1)

Beaker	C_2
Date	5-25-78
X_{FI} (%)	61.62
X_{CI} (%)	38.38
X_{FO} (%)	76.57
X_{CA} (%)	23.43
G_{SI}	1.84
W_L (gm)	13.23
W_{tl} (gm)	225
W_t-W_L(gm)	211.77
X_{DI} (%)	50.87
W_{FI} (gm)	79.67
W_{CI} (gm)	49.62
W_{SI} (gm)	129.29
H_{SI} (cm)	0.41
PRESS	0-5.81gm/cm^2
H_i (IN)	---
H (IN)	2.00
e	11.39
X_{WE} (%)	621
TIME	DIAL READING
OMITTED	
PRESS	5.8-11.6gm/cm^2
H_i(IN)	2.00
H_f(IN)	1.75
e	9.85
X_{WE}	537
TIME	DIAL READING
(MIN)	(10^{-3} IN)
0	440
1.0	457
4	475
9	494
16	515
36	554
70	600
144	650
196	669
270	684
PRESS	11.63-23.26gm/cm^2
H_i(IN)	1.75
H_f(IN)	1.57
e	8.73
X_{WE}(%)	476
TIME (MIN)	DIAL READING (10^{-3} IN)
0	390
1.0	413
4	426
9	439
16	453
36	480
64	506
225	569
PRESS	23.26-46.51gm/cm^2
H_i(IN)	1.57
H_f(IN)	1.34
e	7.32
X_{WE}(%)	399
TIME (MIN)	DIAL READING (10^{-3} IN)
0	320
1	354
4	370
9	387
16	404
36	441
64	475
121	520
196	542
256	550

DIAL READING x 10^{-3} IN







APPENDIX C

VANE SHEAR STRENGTH

TABLE C-1.--Vane Shear Data, Anaerobic, Stage I.

BEAKER DESIGNATION	A						B					
Consolidation Press. gm/cm^2	11.63		23.26		34.88		11.63		23.26		34.88	
Vane Constant, k, cm^3	1.18	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	12	12	26	28	70	70	16	18	33	32	87	85
Vane Shear Strength, gm/cm^2	15.37	15.37	33.3	35.86	89.65	89.65	20.49	23.05	42.26	40.98	111.42	108.66
BEAKER DESIGNATION	C						D					
Consolidation Press. gm/cm^2	11.63		23.26		34.88		11.63		23.26		34.88	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	26	25	49	58	45	55	16	15	32	43	41	47
Vane Shear Strength, gm/cm^2	33.30	32.02	62.76	74.28	57.63	70.44	20.49	19.21	40.98	55.07	52.51	60.19
BEAKER DESIGNATION	E						F					
Consolidation Press. gm/cm^2	11.63		23.26		34.88		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	19	20	42	40	78	85	9	9	15	16	26	28
Vane Shear Strength, gm/cm^2	24.33	25.61	53.79	51.23	99.90	108.86	11.53	11.53	19.21	20.49	33.30	35.86
BEAKER DESIGNATION	G						H					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	9	10	16	17	40	37	10	10	16	16	40	39
Vane Shear Strength, gm/cm^2	11.53	12.81	20.49	21.77	51.23	47.39	12.8	12.8	20.49	20.49	51.23	49.95

Su = ΦK = Vane Shear Strength

TABLE C-1.--Vane Shear Data, Anaerobic, Stage I. (Continue 1)

BEAKER DESIGNATION	I						J					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	13	13	26	28	45	53	15	14	32	30	64	60
Vane Shear Strength, gm/cm^2	16.7	16.7	33.3	35.9	57.6	67.9	19.2	17.9	41	38.4	82	76.8
BEAKER DESIGNATION	K						L					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	16	17	32	29	60	61	12	13	26	24	47	29
Vane Shear Strength, gm/cm^2	20.5	21.8	41	37.1	76.8	78	15.4	16.7	33.3	30.7	60.2	62.8
BEAKER DESIGNATION	M						N					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	10	12	26	26	46	49	12	14	30	33	55	60
Vane Shear Strength, gm/cm^2	12.8	15.4	33.3	33.3	58.9	62.8	15.4	17.93	38.4	42.26	70.4	76.8
BEAKER DESIGNATION	O						P					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	12	14	31	32	74	74	14	15	28	28	60	62
Vane Shear Strength, gm/cm^2	15.37	17.93	39.70	40.98	94.77	94.77	17.93	19.21	35.86	35.86	76.84	79.40

Su = ΦK = Vane Shear Strength

TABLE C-1.--Vane Shear Data, Anaerobic, Stage I. (Continue 2)

BEAKER DESIGNATION	Q						R					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	15	15	30	31	57	61	16	18	36	33	68	65
Vane Shear Strength, gm/cm^2	19.21	19.21	38.42	39.70	73.00	78.12	20.49	23.04	46.11	42.26	87.08	83.25
BEAKER DESIGNATION	13						14					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	-	-	-	-
Pointer Rotation, Φ, deg.	16	16	32	32	60	65	16	15	-	-	-	-
Vane Shear Strength, gm/cm^2	20.49	20.49	41	41	76.84	83.25	20.48	19.20	-	-	-	-
BEAKER DESIGNATION	15						16					
Consolidation Press. gm/cm^2	5.81		11.63		-		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	-	-	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	31	31	65	63	-	-	28	35	65	68	133	140
Vane Shear Strength, gm/cm^2	39.70	39.70	83.75	80.68	-	-	35.84	44.80	83.2	87.04	170.24	179.20
BEAKER DESIGNATION	17						18					
Consolidation Press. gm/cm^2	5.81		11.63		-		5.81		-		-	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	-	-	1.28	1.28	-	-	-	-
Pointer Rotation, Φ, deg.	43	40	86	84	-	-	37	38	-	-	-	-
Vane Shear Strength, gm/cm^2	55.07	51.23	10.14	107.58	-	-	47.36	48.64	-	-	-	-

Su = ΦK = Vane Shear Strength

TABLE C-2.--Vane Shear Data, Aerobic, Stage I. (Continue 3)

BEAKER DESIGNATION	1						2					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	-	-	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	22	28	38	34	-	-	20	21	22	26	32	29
Vane Shear Strength, gm/cm^2	28.18	35.86	48.67	43.54	-	-	25.61	26.89	28.18	32.02	40.98	37.14
BEAKER DESIGNATION	3						4					
Consolidation Press. gm/cm^2	0		5.81		11.63		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	-	-
Pointer Rotation, Φ, deg.	37	40	64	55	73	72	30	30	47	40	-	-
Vane Shear Strength, gm/cm^2	47.36	51.20	81.92	70.40	93.44	92.16	38.40	38.40	60.16	51.20	-	-
BEAKER DESIGNATION	5						6					
Consolidation Press. gm/cm^2	0		5.81		11.63		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	40	40	55	48	65	70	45	47	68	67	97	100
Vane Shear Strength, gm/cm^2	51.20	51.20	70.40	61.44	83.20	89.60	57.60	60.16	87.04	85.76	124.2	128
BEAKER DESIGNATION	7						8					
Consolidation Press. gm/cm^2	0		5.81		11.63		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	40	41	67	66	80	82	37	39	50	57	78	76
Vane Shear Strength, gm/cm^2	51.20	52.48	85.76	84.48	102.4	104.96	47.36	49.92	64	72.96	99.84	97.28

Su = ΦK = Vane Shear Strength

TABLE C-2.--Vane Shear Data, Aerobic, Stage I. (Continue 4)

BEAKER DESIGNATION	9						10					
Consolidation Press. gm/cm^2	0		5.81		11.63		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	36	38	48	49	66	64	52	58	78	76	105	93
Vane Shear Strength, gm/cm^2	46.08	48.64	61.44	62.72	84.48	81.92	66.56	74.24	99.84	97.28	134.4	119
BEAKER DESIGNATION	11						12					
Consolidation Press. gm/cm^2	0		5.81		11.63		0		5.81		11.63	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	38	50	80	72	100	91	55	60	80	88	100	110
Vane Shear Strength, gm/cm^2	48.64	64	102.4	92.16	128	116.48	70.40	76.80	102.4	112.64	128	140.8
BEAKER DESIGNATION												
Consolidation Press. gm/cm^2												
Vane Constant, k, cm^3												
Pointer Rotation, Φ, deg.												
Vane Shear Strength, gm/cm^2												
BEAKER DESIGNATION												
Consolidation Press. gm/cm^2												
Vane Constant, k, cm^3												
Pointer Rotation, Φ, deg.												
Vane Shear Strength, gm/cm^2												

Su = ΦK = Vane Shear Strength

TABLE C-3.--Vane Shear Data, Anaerobic, Stage II.

BEAKER DESIGNATION	A						B					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	5	6	10	12	23	24	7	8	14	16	27	24
Vane Shear Strength, gm/cm^2	6.4	7.7	12.8	15.4	29.5	30.7	9.0	10.2	17.9	20.5	34.6	30.7
BEAKER DESIGNATION	C						D					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	3	4	7	7	13	14	5	5	10	11	19	20
Vane Shear Strength, gm/cm^2	3.8	5.1	9.0	9.0	16.6	17.9	6.4	6.4	12.8	14.1	24.3	25.6
BEAKER DESIGNATION	E*						F*					
Consolidation Press. gm/cm^2	-		-		-		-		-		-	
Vane Constant, k, cm^3	-	-	-	-	-	-	-	-	-	-	-	-
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	-	-	-	-	-	-
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	-	-	-	-	-	-
BEAKER DESIGNATION	G						H					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	9	9	19	18	37	39	4.5	4.5	9	9	27	28
Vane Shear Strength, gm/cm^2	11.5	11.5	24.3	23.1	47.4	49.9	5.8	5.8	11.5	11.5	34.6	35.9

*No data, insufficient material remaining after cecomposition.

TABLE C-3.--Vane Shear Data, Anaerobic, Stage II. (Continue 1)

BEAKER DESIGNATION	I*						J*					
Consolidation Press. gm/cm^2	-		-		-		-		-		-	
Vane Constant, k, cm^3	-	-	-	-	-	-	-	-	-	-	-	-
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	-	-	-	-	-	-
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	-	-	-	-	-	-
BEAKER DESIGNATION	K*						L*					
Consolidation Press. gm/cm^2	-		-		-		-		-		-	
Vane Constant, k, cm^3	-	-	-	-	-	-	-	-	-	-	-	-
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	-	-	-	-	-	-
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	-	-	-	-	-	-
BEAKER DESIGNATION	M						N					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	7	7	16	15	31	32	8	9	18	17	35	37
Vane Shear Strength, gm/cm^2	9.0	9.0	20.5	19.2	39.7	41.0	10.2	11.5	23.1	21.8	44.8	47.4
BEAKER DESIGNATION	O*						P*					
Consolidation Press. gm/cm^2	-		-		-		-		-		-	
Vane Constant, k, cm^3	-	-	-	-	-	-	-	-	-	-	-	-
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	-	-	-	-	-	-
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	-	-	-	-	-	-

*No data, insufficient material remaining after decomposition.

TABLE C-3.--Vane Shear Data, Anaerobic, Stage II. (Continue 2)

BEAKER DESIGNATION	Q*						R*					
Consolidation Press. gm/cm^2	-		-		-		-		-		-	
Vane Constant, k, cm^3	-	-	-	-	-	-	-	-	-	-	-	-
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	-	-	-	-	-	-
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	-	-	-	-	-	-
BEAKER DESIGNATION	13						14					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	10	10	22	20	40	40	7	6	12	12	24	23
Vane Shear Strength, gm/cm^2	12.8	12.8	28.2	25.6	51.2	51.2	9.0	7.7	15.4	15.4	30.7	29.5
BEAKER DESIGNATION	15						16					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	11	10	20	21	43	39	10	10	21	20	40	38
Vane Shear Strength, gm/cm^2	14.1	12.8	25.6	26.9	55.1	49.9	12.8	12.8	26.9	25.6	51.2	48.7
BEAKER DESIGNATION	17						18					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	19	19	36	37	78	78	13	13	26	27	53	55
Vane Shear Strength, gm/cm^2	24.3	24.3	46.1	47.4	99.9	99.9	16.6	16.6	33.3	34.6	67.9	70.4

*No data, insufficient material remaining after decomposition.

TABLE C-4.--Vane Shear Data, Aerobic, Stage II.

BEAKER DESIGNATION	1						2					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	
Pointer Rotation, Φ, deg.	12	11	17	17	29	30	7	6	15	15	23	24
Vane Shear Strength, gm/cm^2	15.4	14.1	21.8	21.8	37.1	38.4	9.0	7.7	19.2	19.2	29.5	30.7
BEAKER DESIGNATION	3						4					
Consolidation Press. gm/cm^2	-		-		-		5.81		11.63		23.26	
Vane Constant, k, cm^3	-	-	-	-	-	-	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	-	-	-	-	-	-	9	9	21	21	25	25
Vane Shear Strength, gm/cm^2	-	-	-	-	-	-	11.5	11.5	26.9	26.9	32.0	32.0
BEAKER DESIGNATION	*											
Consolidation Press. gm/cm^2												
Vane Constant, k, cm^3												
Pointer Rotation, Φ, deg.												
Vane Shear Strength, gm/cm^2												
BEAKER DESIGNATION												
Consolidation Press. gm/cm^2												
Vane Constant, k, cm^3												
Pointer Rotation, Φ, deg.												
Vane Shear Strength, gm/cm^2												

*Beaker Designations 5 through 12 show no data, insufficient material remaining after decomposition.

TABLE C-5.--Vane Shear Data, Anaerobic, Stage III-O through III-7.

BEAKER DESIGNATION	A_1* (0 Days)						A_5 (0 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.64		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, ϕ, deg.	18	21	36	36	70	72	18	18	35	38		
Vane Shear Strength, gm/cm^2	23.1	26.9	46.1	46.1	89.7	92.2	23.0	23.0	44.8	48.6		
BEAKER DESIGNATION	B_1* (0 Days)						B_5 (0 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, ϕ, deg.	20	20	38	36	79	76	22	21	44	42		
Vane Shear Strength, gm/cm^2	25.6	25.6	48.7	46.1	101	97.3	28.2	26.9	56.3	53.8		
BEAKER DESIGNATION	C_1* (0 Days)						C_5 (0 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		--		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28			1.28	1.28	1.28	1.28		
Pointer Rotation, ϕ, deg.	27	29	54	56			27	26	52	50		
Vane Shear Strength, gm/cm^2	34.6	37.1	69.2	71.7			34.6	33.3	66.6	64.0		
BEAKER DESIGNATION	A_1* (7 Days)						A_5 (7 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, ϕ, deg.	9	8	19	18	36	38	10	12	20	22		
Vane Shear Strength, gm/cm^2	11.5	10.3	24.3	23.1	46.1	48.6	12.8	15.4	25.6	28.2		

*Sodium bicarbonate added before test, after for all others.

TABLE C-5.--Vane Shear Data, Anaerobic, Stage III-O through III-7. (Continue 1)

BEAKER DESIGNATION	B_1* (7 Days)						B_5 (7 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		--		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28			1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	14	13	26	26			17	16	31	--		
Vane Shear Strength, gm/cm^2	17.9	16.6	33.3	33.3			21.8	20.5	39.7			
BEAKER DESIGNATION	C_1* (7 Days)						C_5 (7 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		--		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28			1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	24	22	44	45			18	17	32	36		
Vane Shear Strength, gm/cm^2	30.7	28.2	56.3	57.6			23	21.8	41.9	46.1		
BEAKER DESIGNATION	A_1* (14 Days)						A_5 (14 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	5	5	8	9	17	19	5	5	9	--		
Vane Shear Strength, gm/cm^2	6.4	6.4	10.2	11.5	21.8	24.3	6.4	6.4	11.5	--		
BEAKER DESIGNATION	B_1* (14 Days)						B_5 (14 Days					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	7	7	14	14	27	29	7	8	17	17		
Vane Shear Strength, gm/cm^2	9.0	9.0	17.9	17.9	34.6	37.1	9.0	10.2	21.8	21.8		

*Sodium bicarbonate added before test, after for all others.

TABLE C-5.--Vane Shear Data, Anaerobic, Stage III-O through III-7. (Continue 2)

BEAKER DESIGNATION	C_1* (14 Days)						C_5 (14 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		--		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28			1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	8	8	15	16			10	12	19	20		
Vane Shear Strength, gm/cm^2	10.2	10.2	19.2	20.5			12.8	15.4	24.3	25.6		
BEAKER DESIGNATION	A_2 (21 Days)						B_2 (21 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	5	5	10	10	20	21	5	5	10	11	19	22
Vane Shear Strength, gm/cm^2	6.4	6.4	12.8	12.8	25.6	26.9	6.4	6.4	12.8	14.1	24.3	28.2
BEAKER DESIGNATION	C_2 (21 Days)						A_4 (35 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		--	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28		
Pointer Rotation, Φ, deg.	5	5	10	10	22	19	3	4	7	7		
Vane Shear Strength, gm/cm^2	6.4	6.4	12.8	12.8	28.2	24.3	3.8	5.1	9.0	9.0		
BEAKER DESIGNATION	B_1 (35 Days)						C_4 (35 Days)					
Consolidation Press. gm/cm^2	5.81		11.63		23.26		5.81		11.63		23.26	
Vane Constant, k, cm^3	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pointer Rotation, Φ, deg.	5	5	9	10	19	18	4	4	8	-	16	15
Vane Shear Strength, gm/cm^2	6.4	6.4	11.5	12.8	24.3	23.0	5.1	5.1	10.2	-	20.5	19.2

*Beakers A, B, and C were not tested at 49 days for shear strength.

APPENDIX D

ORGANIC CONTENT DATA

TABLE D-1.--Organic Content Data, Anaerobic, Stage I.

BEAKER DESIGNATION	A		B		C		D	
DATE (DURATION, DAYS)	December 16, 1977		December 17, 1977		December 18, 1977		December 18, 1977	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	18.00		30.95		17.45		17.70	
WT (CRUCIBLE) (gm), W_C	19.464	20.376	19.467	20.381	19.471	20.385	19.467	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	25.550	28.726	27.995	27.494	26.237	27.580	25.630	28.381
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	24.174	26.805	26.390	26.183	24.905	26.181	24.220	26.781
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	30.89	31.38	26.15	25.70	26.90	23.49	32.13	27.92
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	66.53	67.04	69.51	71.17	67.25	69.46	67.01	68.95
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-1.--Organic Content Data, Anaerobic, Stage I. (Continue 1)

BEAKER DESIGNATION	E		F		G		H	
DATE (DURATION, DAYS)	December 19, 1977		December 20, 1977		December 22, 1977		December 22, 1977	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	10.46		14.60		12.27		6.65	
WT (CRUCIBLE) (gm), W_C	19.475	-	20.385	-	19.475	20.385	19.475	-
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	26.449	-	30.119	-	23.944	25.735	23.910	-
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	24.945	-	26.193	-	21.025	22.206	21.253	-
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	29.52	-	30.0	-	59.49	60.24	59.49	-
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	69.09	-	70.00	-	40.51	39.76	40.51	-
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-1.--Organic Content Data, Anaerobic, Stage I. (Continue 2)

BEAKER DESIGNATION	I		J		K		L	
DATE (DURATION, DAYS)	December 23, 1977		December 24, 1977		December 25, 1977		December 26, 1977	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	7.90		6.65		5.90		6.30	
WT (CRUCIBLE) (gm), W_C	20.385	-	20.385	-	19.475	-	19.475	-
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	25.654	-	24.815	-	23.410	-	23.673	-
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	23.025	-	21.870	-	20.786	-	21.992	-
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	60.28	-	60.85	-	61.00	-	60.90	-
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	39.72	-	29.15	-	39.00	-	39.10	-
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

   $X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-1.--Organic Content Data, Anaerobic, Stage I. (Continue 3)

BEAKER DESIGNATION	M		N		O		P	
DATE (DURATION, DAYS)	December 27, 1977		December 28, 1977		December 29, 1977		December 39, 1977	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	5.35		7.78		8.12		9.59	
WT (CRUCIBLE) (gm), W_C	20.385	-	19.475	20.385	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.950	-	22.256	23.827	22.389	23.965	23.333	24.197
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	21.843	-	20.657	20.958	19.969	21.003	20.130	21.017
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	79.05	-	79.94	80.00	80.21	79.85	80.17	80.63
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	20.95	-	20.06	20.00	19.79	20.15	19.82	19.37
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

   $X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-1.--Organic Content Data, Anaerobic, Stage I. (Continue 4)

BEAKER DESIGNATION	Q		R		13		14	
DATE (DURATION, DAYS)	December 31, 1977		January 1, 1978		January 14, 1978		January 15, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	8.11		9.12		15.92		14.59	
WT (CRUCIBLE) (gm), W_C	19.475	20.389	19.477	20.388	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	22.726	23.624	23.050	24.112	26.548	26.045	25.219	26.310
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.038	20.930	20.093	21.015	23.655	23.855	22.907	23.881
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	79.79	80.35	79.87	80.32	30.98	28.39	30.21	21.09
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	20.21	19.65	20.13	19.68	69.02	71.61	69.79	68.91
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-1.--Organic Content Data, Anaerobic, Stage I. (Continue 5)

BEAKER DESIGNATION	15		16		17		18	
DATE (DURATION, DAYS)	January 16, 1978		January 17, 1978		January 18, 1978		January 19, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	9.36		11.48		7.57		9.21	
WT (CRUCIBLE) (gm), W_C	19.475	20.385	19.475	20.385	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	22.517	24.829	23.926	25.121	22.817	23.099	23.248	23.980
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.470	21.820	20.994	22.008	20.035	20.847	20.111	21.007
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	61.80	62.28	60.13	59.98	80.43	80.11	80.30	79.78
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	38.20	37.72	39.87	40.02	19.57	19.89	19.70	20.22
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

   $X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-2.--Organic Content Data, Aerobic, Stage I.

BEAKER DESIGNATION	1		2		3		4	
DATE (DURATION, DAYS)	January 2, 1978		January 3, 1978		January 4, 1978		January 5, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	8.52		12.22		11.32		10.78	
WT (CRUCIBLE) (gm), W_C	19.475	20.385	19.475	20.385	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	22.683	23.992	24.456	25.183	23.891	25.027	23.601	24.882
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	21.372	22.187	22.449	23.247	22.103	23.176	21.959	23.080
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	30.93	29.86	30.26	30.33	30.48	29.88	29.69	30.00
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	69.07	70.14	69.74	69.67	69.22	70.22	70.31	70.00
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-2.--Organic Content Data, Aerobic, Stage I. (Continue 1)

BEAKER DESIGNATION	5		6		7		8	
DATE (DURATION, DAYS)	January 6, 1978		January 7, 1978		January 8, 1978		January 9, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	8.67		7.79		8.85		7.89	
WT (CRUCIBLE) (gm), W_C	19.475	20.385	19.475	20.385	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	22.678	24.119	22.823	23.391	23.019	23.924	22.815	23.357
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.571	21.668	20.591	21.405	20.668	21.584	20.622	21.402
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	60.05	59.87	61.08	60.38	60.67	60.44	59.89	60.05
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	39.95	40.13	38.92	39.62	39.33	39.56	40.11	39.95
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-2.--Organic Content Data, Aerobic, Stage I. (Continue 2)

BEAKER DESIGNATION	9		10		11		12	
DATE (DURATION, DAYS)	January 10, 1978		January 11, 1978		January 12, 1978		January 13, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	8.12		7.34		7.12		7.71	
WT (CRUCIBLE) (gm), W_C	19.475	20.385	19.475	20.385	19.475	20.385	19.475	20.385
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.089	23.265	22.177	23.558	22.429	23.128	22.951	23.074
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.087	20.858	19.945	20.925	19.978	20.850	20.076	20.824
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	80.21	80.80	79.69	80.13	80.11	80.20	79.81	80.84
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	19.79	19.20	20.31	19.87	19.89	19.80	20.19	19.06
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II.

BEAKER DESIGNATION	A		B		C		D	
DATE (DURATION, DAYS)	February 13, 1978		February 14, 1978		February 15, 1978		February 16, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	16.00		21.81		26.10		25.91	
WT (CRUCIBLE) (gm), W_C	19.471	20.386	19.478	20.388	19.485	20.392	19.488	20.397
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	26.649	28.684	28.505	29.170	32.065	30.034	29.133	31.480
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	23.685	25.342	25.333	26.113	28.441	27.155	25.885	27.750
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	31.42	30.33	24.24	23.86	16.85	18.08	23.53	22.51
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	68.57	69.77	75.76	76.14	83.15	81.92	77.47	77.49
% DECOMPOSITION AT INTERVAL I, X_{DI}	10.40		24.83		54.18		38.32	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II. (Continue 1)

BEAKER DESIGNATION	E		F		G		H	
DATE (DURATION, DAYS)	February 17, 1978		February 18, 1978		February 19, 1978		February 20, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	37.00		25.27		11.19		15.11	
WT (CRUCIBLE) (gm), W_C	19.492	20.405	19.483	20.409	19.483	20.400	19.491	20.412
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	33.675	36.228	28.814	31.295	23.368	25.463	24.944	27.045
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	30.158	32.358	26.201	28.315	21.008	22.365	22.071	23.382
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	11.85	11.77	15.91	15.17	54.15	54.67	44.74	47.70
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	88.15	88.23	84.09	84.83	45.85	45.33	55.26	52.30
% DECOMPOSITION AT INTERVAL I, X_{DI}	70.07		57.07		20.00		41.48	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II. (Continue 2)

BEAKER DESIGNATION	I		J		K		L	
DATE (DURATION, DAYS)	February 21, 1978		February 22, 1978		February 23, 1978		February 24, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	22.01		14.65		18.21		19.17	
WT (CRUCIBLE) (gm), W_C	19.493	20.416	19.513	20.430	19.512	20.428	19.514	20.484
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	28.106	29.414	24.700	26.965	26.576	27.929	25.811	26.855
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	24.113	25.234	21.796	23.330	23.128	24.181	23.200	24.670
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	37.35	37.46	48.59	48.17	40.21	41.56	41.81	40.44
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	62.65	62.54	51.41	51.83	59.79	58.44	58.19	59.56
% DECOMPOSITION AT INTERVAL I, X_{DI}	60.63		39.70		55.77		54.70	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II. (Continue 3)

BEAKER DESIGNATION	M		N		O		P	
DATE (DURATION, DAYS)	February 25, 1978		February 26, 1978		February 27, 1978		February 28, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	10.40		12.45		16.61		10.40	
WT (CRUCIBLE) (gm), W_C	19.489	20.417	19.502	20.431	19.509	20.434	19.527	20.473
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.437	24.789	24.550	25.340	25.095	28.135	23.350	24.969
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.572	21.603	21.113	22.011	21.480	23.376	20.819	21.899
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	67.96	68.32	62.72	62.41	58.79	55.38	60.53	62.95
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	32.04	31.68	37.28	37.59	41.21	44.62	39.47	37.05
% DECOMPOSITION AT INTERVAL I, X_{DI}	43.32		58.15		66.74		60.65	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II. (Continue 4)

BEAKER DESIGNATION	Q		R		13		14	
DATE (DURATION, DAYS)	March 1, 1978		March 2, 1978		March 15, 1978		March 16, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	9.99		15.42		15.68		23.90	
WT (CRUCIBLE) (gm), W_C	19.524	20.457	19.515	20.455	19.543	20.466	19.513	20.445
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.239	24.735	25.588	26.716	25.513	27.041	29.550	29.525
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.625	21.725	21.594	22.594	22.978	24.225	26.272	26.413
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	65.38	65.33	60.02	60.10	32.80	33.22	21.35	23.23
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	34.62	34.67	39.98	39.90	67.20	66.78	78.65	76.77
% DECOMPOSITION AT INTERVAL I, X_{DI}	53.06		62.71		0		35.10	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-3.--Organic Content Data, Anaerobic, Stage II. (Continue 5)

BEAKER DESIGNATION	15		16		17		18	
DATE (DURATION, DAYS)	March 17, 1978		March 18, 1978		March 19, 1978		March 20, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	10.38		11.63		7.38		10.96	
WT (CRUCIBLE) (gm), W_C	19.520	20.462	19.568	20.477	19.545	20.468	19.582	20.484
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.826	24.460	24.126	25.221	22.293	23.620	23.366	25.471
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.825	21.681	21.655	22.611	20.069	21.061		
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	64.60	64.39	46.52	47.46	77.73	78.03	60.55	62.15
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	35.40	35.61	53.48	52.54	22.27	21.97	39.45	37.85
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		41.05		13.46		60.42	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

   $X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-4.--Organic Content Data, Aerobic, Stage II.

BEAKER DESIGNATION	1		2		3		4	
DATE (DURATION, DAYS)	March 4, 1978		March 4, 1978		March 5, 1978		March 7, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	34.25		14.63		22.40		20.88	
WT (CRUCIBLE) (gm), W_C	19.561	20.463	19.542	-	20.463	-	20.474	-
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	34.151	32.271	34.404	-	36.014	-	34.396	-
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	28.772	28.454	29.557	-	31.708	-	30.382	-
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	26.76	27.13	19.34	-	15.54	-	16.88	-
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	73.74	72.87	80.66	-	84.46	-	83.12	-
% DECOMPOSITION AT INTERVAL I, X_{DI}	16.65		44.85		57.43		52.27	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

   $X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-4.--Organic Content Data, Aerobic, Stage II. (Continue 1)

BEAKER DESIGNATION	5		6		7		8	
DATE (DURATION, DAYS)	March 7, 1978		March 9, 1978		March 9, 1978		March 10, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	17.24		27.99		23.82		29.94	
WT (CRUCIBLE) (gm), W_C	19.559	-	19.543	20.459	19.545	20.459	19.544	20.460
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	31.052	-	30.134	32.261	28.238	30.820	33.098	30.861
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	25.655	-	26.016	27.692	25.054	25.982	27.855	26.849
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	38.05	-	28.61	28.42	25.98	26.47	28.38	28.25
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	61.95	-	71.39	71.58	74.02	73.53	71.62	71.75
% DECOMPOSITION AT INTERVAL I, X_{DI}	58.98		74.21		76.86		73.55	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-4.--Organic Content Data, Aerobic, Stage II. (Continue 2)

BEAKER DESIGNATION	9		10		11		12	
DATE (DURATION, DAYS)	March 11, 1978		March 12, 1978		March 13, 1978		March 14, 1978	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	23.53		22.54		24.59		27.68	
WT (CRUCIBLE) (gm), W_C	19.540	20.458	19.544	20.470	19.553	20.481	19.549	20.464
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	28.592	30.227	28.233	29.813	29.945	29.760	29.450	32.709
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	23.704	24.639	23.677	24.768	25.219	25.579	24.600	26.789
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	46.27	50.00	44.44	46.27	36.32	35.82	40.41	39.67
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	53.73	50.00	55.56	53.73	63.68	64.17	59.59	60.33
% DECOMPOSITION AT INTERVAL I, X_{DI}	77.53		79.14		86.04		83.70	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7.

BEAKER DESIGNATION	A_1*		A_5		B_1*		B_5	
DATE (DURATION, DAYS)	April 4, 1978 (0)		July 3, 1978 (0)		April 5, 1978 (0)		July 4, 1978 (0)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	17.2		13.1		9.85		9.9	
WT (CRUCIBLE) (gm), W_C	19.640	20.578	20.449	19.524	19.628	20.545	19.531	20.458
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	27.311	29.630	26,153	25,436	24,508	24.966	23,452	24,522
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	24,155	25.988	23.781	23.110	21.332	22.184	20.832	21.788
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	31.25	30.17	31.77	29.15	59.22	56.70	61.25	61.78
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	68.75	69.83	68.23	70.85	40.78	43.30	38.75	38.22
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0		0	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

*Sodium bicarbonate added before test, after for all others.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 1)

BEAKER DESIGNATION	C_1*		C_5		A_1*		A_5	
DATE (DURATION, DAYS)	April 6, 1978 (0)		July 5, 1978 (0)		April 11, 1978 (7)		July 10, 1978 (7)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	7.2		8.3		15.4		21.4	
WT (CRUCIBLE) (gm), W_C	19.625	20.542	20.456	19.525	19.610	20.525	19.524	20.456
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.118	24.961	23.378	22.459	26,750	27.798	26.646	28.743
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.329	21.424	20.905	19.985	23.842	24.850	23.852	25.497
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	76.46	76.69	82.05	81.69	30.77	30.55	29.02	28.95
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	23.54	23.31	17.95	18.31	69.23	69.45	70.98	71.05
% DECOMPOSITION AT INTERVAL I, X_{DI}	0		0		0.23		6.80	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

*Sodium bicarbonate added before test, after for all others.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 2)

BEAKER DESIGNATION	B_1*		B_5		C_1*		C_5	
DATE (DURATION, DAYS)	April 12, 1978 (7)		July 11, 1978 (7)		April 13, 1978 (7)		July 12, 1978 (7)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	11.10		10.20		9.2		10.6	
WT (CRUCIBLE) (gm), W_C	19.616	20.528	19.526	20.459	19.615	20.518	19.526	20.459
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	25.310	24.009	22.576	24.952	22.588	24.052	22.758	24.271
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	21.571	21.854	20.620	22.047	20.147	21.153	20.084	21.073
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	59.90	55.51	58.11	58.72	79.10	79.01	79.83	81.19
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	41.10	44.49	41.89	41.28	20.90	20.99	20.17	18.81
% DECOMPOSITION AT INTERVAL I, X_{DI}	1.06		12.12		0		10.60	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

*Sodium bicarbonate added before test, after for all others.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 3)

BEAKER DESIGNATION	A_1*		A_5		B_1*		B_5	
DATE (DURATION, DAYS)	April 18, 1978 (14)		July 17, 1978 (14)		April 19, 1978(14)		July 18, 1978 (14)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	19.46		--		16.7		--	
WT (CRUCIBLE) (gm), W_C	19.607	20.513	14.524	20.456	19.613	20.521	19.528	20.460
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	28.379	29.200	27.627	30.851	22.337	23.521	23.870	27.193
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	25.149	26.106	24.720	27.325	20.619	21.512	21.299	23.400
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	26.21	24.80	25.10	22.82	56.86	56.55	52.36	49.99
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	73.79	75.20	74.90	77.18	43.14	43.45	47.64	51.00
% DECOMPOSITION AT INTERVAL I, X_{DI}	22.73		28.06		5.02		35.70	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

*Sodium bicarbonate added before test, after for all others.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 4)

BEAKER DESIGNATION	C_1*		C_5		A_2		B_2	
DATE (DURATION, DAYS)	April 20, 1978 (14)		July 19, 1978 (14)		April 25, 1978 (21)		April 26, 1978(21)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	10.8		--		26.4		17.80	
WT (CRUCIBLE) (gm), W_C	19.619	20.530	19.530	20.461	19.610	20.513	19.640	20.527
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	23.039	24.932	23.616	25.069	28.605	29.295	24.262	25.172
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.334	21.420	20.425	21.434	25.539	26.310	21.654	22.505
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	75.58	76.39	74.42	75.34	23.00	22.90	49.11	50.26
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	24.42	23.61	25.58	24.66	77.00	77.10	50.89	49.74
% DECOMPOSITION AT INTERVAL I, X_{DI}	3.21		34.00		32.80		28.36	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

*Sodium bicarbonate added before test, after for all others.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 5)

BEAKER DESIGNATION	C_2		A_4		B_1		C_4	
DATE (DURATION, DAYS)	April 27, 1978(21)		July 9, 1978 (35)		May 10, 1978 (35)		May 11, 1978 (35)	
TEST NO.	1	2	1	2	1	2	1	2
ASH ANALYSTS SAMPLE WT (gm), W_L	13.23		26.45		16.8		13.3	
WT (CRUCIBLE) (gm), W_C	19.608	20.512	19.607	20.513	19.621	20.528	19.620	20.525
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	24.015	25.291	29.290	30.279	26.213	27.793	23.540	25.892
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	20.696	21.723	26.145	27.126	22.849	23.689	20.759	22.147
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	71.16	70.40	21.14	20.91	42.80	49.18	66.05	64.70
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	28.84	29.60	78.86	74.09	57.20	50.82	33.94	35.30
% DECOMPOSITION AT INTERVAL I, X_{DI}	25.88		39.91		38.26		42.21	

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

TABLE D-5.--Organic Content Data, Anaerobic, Stage III-0 through III-7. (Continue 6)

BEAKER DESIGNATION	A_4		B_4		C_2			
DATE (DURATION, DAYS)	May 23, 1978 (49)		May 24, 1978 (49)		May 25, 1978 (49)			
TEST NO.	1	2	1	2	1	2		
ASH ANALYSTS SAMPLE WT (gm), W_L	--		--		--			
WT (CRUCIBLE) (gm), W_C	19.606	20.510	19.622	20.542	19.620	20.537		
WT (CRUCIBLE + SAMPLE) (gm) BEFORE BURN, WT_1	28.177	32.485	26.125	26.753	25.300	26.294		
WT (CRUCIBLE + SAMPLE) (gm) AFTER BURN, WT_1	25.890	29.310	22.947	23.730	21.462	22.453		
ORGANIC CONTENT (%) AT INTERVAL I, X_{FI}	14.37	14.17	40.28	40.05	62.12	61.13		
CLAY CONTENT (%) AT INTERVAL I, X_{CI}	85.63	85.83	59.72	59.95	37.88	38.87		
% DECOMPOSITION AT INTERVAL I, X_{DI}	62.44		51.4		50.87			

NOTE: 1. Temperature of all Tests = 900°C

2. Duration of all Tests = 1.5 hours

3. $X_{CI} = 1.168 \left(\frac{WT_2 - W_C}{W_{T1} - W_C}\right)$

$X_{FI} = 1 - X_{CI}$

4. $X_{DI} = \frac{1 - X_{FI}/X_{FO}}{1 - X_{FI}}$

5. See Section IV-E for Details on Test Procedure.

APPENDIX E

HYDROGEN ION CONCENTRATION (pH) DATA

TABLE E-1.--pH Data, Anaerobic, Stage I through II.

BEAKER DESIGNATION	A					B					C				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	5.8	8.1	7.5	7.5	7.6	6.8	6.2	6.6	7.1	7.6	7.0	6.3	5.6	5.5	6.2
Sodium Bicarbonate added (gm)	25	0	0	0	0	5	20	10	0	0	5	20	15	15	17
New pH	7.5	8.1	7.5	7.5	7.6	7.1	7.0	7.2	7.1	7.6	7.4	7.0	7.0	7.0	7.0
BEAKER DESIGNATION	D					E					F				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.9	7.2	7.0	7.3	6.6	6.9	4.8	6.6	6.6	6.7	7.1	4.8	6.6	6.6	6.7
Sodium Bicarbonate added (gm)	5	0	0	0	10	0	60	10	17	0	0	65	11	15	9
New pH	7.3	7.2	7.0	7.3	7.1	6.9	7.2	6.9	7.1	6.7	7.1	7.2	7.0	7.2	7.0
BEAKER DESIGNATION	G					H					I				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.2	6.8	6.6	6.6	6.7	6.6	6.5	7.1	7.0	6.5	6.3	6.4	6.1	6.3	6.7
Sodium Bicarbonate added (gm)	10	0	17	17	12	6	50	0	0	12	10	50	19	17	0
New pH	7.2	6.8	7.2	7.0	7.0	7.2	7.2	7.1	7.0	7.0	7.1	7.2	7.0	6.9	6.7
BEAKER DESIGNATION	J					K					L				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	7.0	5.8	6.6	6.6	7.2	7.3	4.7	6.6	6.6	6.2	7.3	4.8	7.0	6.8	6.2
Sodium Bicarbonate added (gm)	0	40	8	7	0	0	70	16	10	0	0	80	0	0	0
New pH	7.0	7.1	7.2	7.0	7.2	7.3	7.1	7.3	7.0	6.2	7.3	7.2	7.0	6.8	6.2

TABLE E-1.--pH Data, Anaerobic, Stage I through II. (Continue 1)

BEAKER DESIGNATION	M					N					O				
Detention Time (days)	0	15	30	45	60	0	15	33	45	60	0	15	32	45	60
pH	6.3	6.7	-	6.3	6.2	6.7	6.3	6.3	6.7	6.6	6.6	6.5	5.9	6.2	-
Sodium Bicarbonate added (gm)	10	0	-	16	21	5.0	20	13	9	12	6	30	20	22	-
New pH	6.9	6.7	-	7.0	7.2	7.1	7.2	7.1	7.0	7.0	7.1	7.1	7.0	7.1	-
BEAKER DESIGNATION	P					Q					R				
Detention Time (days)	0	15	31	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.9	6.0	7.0	6.2	6.8	6.9	5.4	5.2	5.2	6.6	7.1	4.9	5.1	5.4	6.3
Sodium Bicarbonate added (gm	0	30	0	24	0	0	20	21	25	6	0	20	29	20	0
New pH	6.9	7.3	7.0	7.0	6.8	6.9	7.2	6.9	7.1	7.4	7.1	7.2	7.2	7.3	6.3
BEAKER DESIGNATION	13					14					15				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.2	5.1	6.9	7.0	7.0	6.2	7.0	6.2	6.6	6.7	6.2	6.2	6.7	6.7	6.6
Sodium Bicarbonate added (gm)	0	21	0	0	0	15	13	12	20	8	10	12	7	5	8
New pH	6.2	7.2	6.9	7.0	7.0	7.6	7.5	7.5	7.2	7.0	7.6	7.5	7.0	7.3	7.2
BEAKER DESIGNATION	16					17					18				
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.7	5.8	6.3	6.8	6.5	7.1	5.6	6.5	6.5	6.5	6.6	5.0	5.5	6.0	6.7
Sodium Bicarbonate added (gm)	10	15	9	0	10	0	15	8	10	9	10	10	15	25	8
New pH	7.3	7.6	6.9	6.8	7.0	7.1	7.6	7.0	7.0	7.0	7.4	7.2	7.3	7.2	7.0

TABLE E-2. pH Data, Anaerobic, Stage III-0 through III-7.

BEAKER DESIGNATION	A_1,	A_2,	A_3,	A_4		B_1,	B_2,	B_3,	B_4		C_1,	C_2,	C_3,	C_4	
Detention Time (days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pH	7.0	5.2	5.0	5.4	6.4	7.0	5.2	4.9	5.8	6.2	7.0	5.0	4.4	5.7	6.2
Sodium Bicarbonate added (gm)	0	20	30	35	11	0	20	37	30	12	0	21	33	30	10
New pH	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
BEAKER DESIGNATION			D					E					F		
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.9	7.2	7.0	7.3	6.6	6.9	4.8	6.6	6.6	6.7	7.1	4.8	6.6	6.6	6.7
Sodium Bicarbonate added (gm)	5	0	0	0	10	0	60	10	17	0	0	65	11	15	9
New pH	7.3	7.2	7.0	7.3	7.1	6.9	7.2	6.9	7.1	6.7	7.1	7.2	7.0	7.2	7.0
BEAKER DESIGNATION			G					H					I		
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	6.2	6.8	6.6	6.6	6.7	6.6	6.5	7.1	7.0	6.5	6.3	6.4	6.1	6.3	6.7
Sodium Bicarbonate added (gm)	10	0	17	17	12	6	50	0	0	12	10	50	19	17	0
New pH	7.2	6.8	7.2	7.0	7.0	7.2	7.2	7.1	7.0	7.0	7.1	7.2	7.0	6.9	6.7
BEAKER DESIGNATION			J					K					L		
Detention Time (days)	0	15	30	45	60	0	15	30	45	60	0	15	30	45	60
pH	7.0	5.8	6.6	6.6	7.2	7.3	4.7	6.6	6.6	6.2	7.3	4.8	7.0	6.8	6.2
Sodium Bicarbonate added (gm)	0	40	8	7	0	0	70	16	10	0	0	80	0	0	0
New pH	7.0	7.1	7.2	7.0	7.2	7.3	7.1	7.3	7.0	6.2	7.3	7.2	7.0	6.8	6.2

APPENDIX F

ASH ANALYSIS DATA

TABLE F-1.--Ash Analysis Data, 100% Cellulose.

T (°C)	100	
W_c (g)	13.901	
$W_c + \overline{W}_{os}$ (g)	23.658	
Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	23.26	3.06
0.50	23.254	4.14
1	23.121	5.51
2	23.034	6.40
12	23.014	6.60

T (°C)	250	
W_c (g)	19.479	
$W_c + \overline{W}_{os}$ (g)	26.906	
Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	26.320	7.89
0.50	26.015	12.00
2.50	22.425	13.01
3.50	22.103	64.67
6	21.648	70.79
7.5	21.492	72.89
12	21.290	75.61

T (°C)	200	
W_c (g)	19.479	
$W_c + \overline{W}_{os}$ (g)	26.533	
Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	26.035	7.06
0.50	25.943	8.51
1.50	25.933	10.39
2.50	25.800	12.45
6	24.645	26.76
12	22.013	64.68

T (°C)	300	
W_c (g)	19.478	
$W_c + \overline{W}_{os}$ (g)	26.253	
Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	24.932	19.60
0.50	22.35	57.61
0.75	21.430	71.19
1	21.314	72.90
1.5	21.190	74.73
2.5	21.040	76.95
12	19.709	96.63

TABLE F-1.--Ash Analysis Data, 100% Cellulose (Continue 1)

T (°C)	350
W_c (g)	19.479
$W_c + \overline{W}_{os}$ (g)	27.157

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	21.760	70.29
0.50	21.178	77.87
1	31.080	79.15
1.5	21.000	80.19
3.5	20.651	84.74
6	20.216	90.40
9	19.715	96.93
12	19.503	99.69

T (°C)	400
W_c (g)	19.478
$W_c + \overline{W}_{os}$ (g)	26.496

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	21.007	78.21
0.50	20.805	81.09
1	20.662	83.13
2	20.472	85.83
3.5	20.113	90.95
5.25	19.817	95.17
8	19.617	98.02
10	19.499	99.70

T (°C)	500
W_c (g)	19.477
$W_c + \overline{W}_{os}$ (g)	26.578

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	20.510	85.46
0.50	20.448	86.33
1	20.318	88.16
2	20.145	90.60
4	19.872	94.44
6	19.604	98.22
8	19.484	99.91

T (°C)	900
W_c (g)	19.484
$W_c + \overline{W}_{os}$ (g)	25.170

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	20.027	90.45
0.50	19.906	92.58
1	19.629	97.45
1.25	19.484	100.00

TABLE F-2.--Ash Analysis Data, 100% Kaolinite.

T (°C)	400
W_c (g)	19.4778
$W_c + \overline{W}_{os}$ (g)	29.356

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	29.258	0.99
0.50	29.245	1.13
1	29.235	1.23
3	29.226	1.32
9	29.213	1.45
12	29.209	1.49

T (°C)	550
W_c (g)	19.487
$W_c + \overline{W}_{os}$ (g)	29.284

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	29.008	2.82
0.50	28.817	4.77
1	28.398	9.04
2	28.050	12.59
3	28.002	13.08
5	27.980	13.31
12	27.969	13.42

T (°C)	500
W_c (g)	19.4763
$W_c + \overline{W}_{os}$ (g)	28.972

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	28.811	1.70
0.50	28.731	2.54
1.0	28.653	3.36
2	28.385	6.18
3	28.208	8.05
6	27.794	12.41
8	27.756	12.81
12	27.738	13.00

T (°C)	600
W_c (g)	19.492
$W_c + \overline{W}_{os}$ (g)	29.534

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.33	28.758	7.73
0.50	28.560	9.70
1	28.210	13.14
2	28.163	13.66
3	28.153	13.72
4	28.151	13.73
8	28.145	13.84
12	28.133	13.95

TABLE F-2.--Ash Analysis Data, 100% Kaolinite (Continue 1)

T (°C)	650
W_c (g)	19.491
$W_c + \overline{W}_{os}$ (g)	29.305

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	28.240	10.85
0.50	28.003	13.26
1	27.933	13.98
5	27.928	14.03
12	27.926	14.05

T (°C)	900
W_c (g)	19.496
$W_c + \overline{W}_{os}$ (g)	28.963

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	27.591	14.45
0.50	27.591	14.45
1	27.591	14.45
12	27.588	14.47

T (°C)	700
W_c (g)	19.488
$W_c + \overline{W}_{os}$ (g)	28.744

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	27.631	12.02
0.50	27.452	13.95
1	27.437	14.12
12	27.428	14.21

T (°C)	
W_c (g)	
$W_c + \overline{W}_{os}$ (g)	

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)

TABLE F-3.--Ash Analysis Data, 100% Montmorillonite.

T (°C)	100
W_c (g)	1.50
$W_c + \overline{W}_{os}$ (g)	30.80

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	30.80	2.33
0.50	30.60	3.00
1	30.20	4.33
2	29.80	5.67
4	29.70	6.00
12	29.70	6.00

T (°C)	400
W_c (g)	20.450
$W_c + \overline{W}_{os}$ (g)	39.017

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	37.630	7.47
0.50	37.615	7.55
1	37.615	7.55
2	37.613	7.56
4	37.613	7.56
12	37.613	7.56

T (°C)	200
W_c (g)	20.457
$W_c + \overline{W}_{os}$ (g)	40.452

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	39.260	4.96
0.50	39.011	7.21
1	38.999	7.27
2	38.998	7.27
4	38.998	7.27
12	38.998	7.27

T (°C)	600
W_c (g)	20.454
$W_c + \overline{W}_{os}$ (g)	38.139

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	36.710	8.08
0.50	36.67	8.30
1	36.616	8.61
4.75	36.257	10.64
12	36.114	11.45

TABLE F-3.--Ash Analysis Data, 100% Mountmorillionite (Continue 1)

T (°C)	700
W_c (g)	20.462
$W_c + \overline{W}_{os}$ (g)	39.969

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	37.940	10.40
0.50	37.713	11.57
1	37.673	11.77
2	37.673	11.77
4	37.673	11.77
12	37.673	11.77

T (°C)	
W_c (g)	
$W_c + \overline{W}_{os}$ (g)	

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)

T (°C)	900
W_c (g)	20.452
$W_c + \overline{W}_{os}$ (g)	37.744

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)
0.25	35.651	12.10
0.05	35.651	12.10
1	35.651	12.10
2	35.651	12.10
4	35.651	12.10
12	35.651	12.10

T (°C)	
W_c (g)	
$W_c + \overline{W}_{os}$ (g)	

Time (hrs)	$W_c + \overline{W}_{os}$ (g)	W_r (%)

APPENDIX G

EXPERIMENTAL RESULTS SUMMARY DATA

TABLE G-1. Experimental Results, Anaerobic, Stage I.

Beaker[a]	A				B			
Date (Duration, Days)	December 15, 1977 (0)				December 16, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.59	9.27	7.67	--	12.01	10.01	7.90	--
Coeff. Consol., c_v (cm^2/sec)	.0983	.0866	.0738	--	.1001	.0909	.0427	--
Equiv. Liq. Limit[b], LL (%)	276	276	276	--	286	286	286	--
Permeability, k (cm/sec)	.00092	.00044	.00026	--	.00093	.00045	.00015	--
Coeff. Comp., av (cm^2/gm)	.0688	.0343	.0229	--	.0731	.0364	.0243	--
Compr. Index, C_c	1.836				1.950			
Coeff. Secondary Comp, C_α (cm)	0.2611				0.3861			
Beaker[a]	C				D			
Date (Duration, Days)	December 17, 1977 (0)				December 18, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.88	9.29	7.85	--	11.83	9.68	7.43	--
Coeff. Consol., c_v (cm^2/sec)	.1710	.1560	.1454	--	.0910	.0599	.0637	--
Equiv. Liq. Limit[b], LL (%)	337	337	337	--	315	315	315	--
Permeability, k (cm/sec)	.00211	.00106	.00068	--	.00084	.00030	.00022	--
Coeff. Comp., av (cm^2/gm)	.1037	.0516	.0345	--	.0781	.0389	.0260	--
Compr. Index, C_c	2.767				2.084			
Coeff. Secondary Comp, C_α (cm)	0.1601				0.1912			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-1. Experimental Results, Anaerobic, Stage I. (Continue 1)

Beaker[a]	E				F			
Date (Duration, Days)	December 19, 1977 (0)				December 20, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.68	9.37	8.32	--	11.42	10.03	8.06	--
Coeff. Consol., c_v (cm^2/sec)	0.1770	0.1703	.0925	--	.1698	.1635	.1130	--
Equiv. Liq. Limit[b], LL (%)	322	322	322	--	311	311	311	--
Permeability, k (cm/sec)	.00230	.00122	.00047	--	.00251	.00136	.00067	--
Coeff. Comp., av (cm^2/gm)	.1104	.055	.0367	--	.1296	.0645	.0431	--
Compr. Index, C_c	2.945				3.458			
Coeff. Secondary Comp, C_α (cm)	0.2177				0.2007			
Beaker[a]	G				H			
Date (Duration, Days)	December 21, 1977 (0)				December 22, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.92	11.75	9.70	--	13.47	12.07	10.25	--
Coeff. Consol., c_v (cm^2/sec)	0.4271	.3385	.2515	--	.8880	.8332	.4353	--
Equiv. Liq. Limit[b], LL (%)	465	465	465	--	471	471	471	--
Permeability, k (cm/sec)	.00560	.00247	.00132	--	.01191	.00625	.00234	--
Coeff. Comp., av (cm^2/gm)	.1370	.0682	.0455	--	.1408	.0701	.0468	--
Compr. Index, C_c	3.654				3.756			
Coeff. Secondary Comp, C_α (cm)	0.1991				0.2346			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-1. Experimental Results, Anaerobic, Stage I (Continue 2)

Beaker[a]	I				J			
Date (Duration, Days)	December 23, 1977 (0)				December 24, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.81	11.45	10.11	--	12.34	10.94	9.66	--
Coeff. Consol., c_v (cm^2/sec)	.9057	.7348	.5430	--	1.496	1.048	.8458	--
Equiv. Liq. Limit[b], LL (%)	554	554	554	--	536	536	550	--
Permeability, k (cm/sec)	.01224	.00556	.00295	--	.01810	.00693	.00400	--
Coeff. Comp., av (cm^2/gm)	.1419	.0707	.0472	--	.1331	.0663	.0442	--
Compr. Index, C_c	3.787				3.551			
Coeff. Secondary Comp, C_α (cm)	0.2334				0.1867			
Beaker[a]	K				L			
Date (Duration, Days)	December 25, 1977 (0)				December 26, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.06	11.06	10.03	--	11.94	10.87	9.67	--
Coeff. Consol., c_v (cm^2/sec)	2.537	.7485	.5559	--	1.613	.7951	.7263	--
Equiv. Liq. Limit[b], LL (%)	550	550	550	--	578	578	578	--
Permeability, k (cm/sec)	.02450	.00385	.00204	--	.01888	.00509	.00333	--
Coeff. Comp., av (cm^2/gm)	.1178	.0587	.0392	--	.1434	.0714	.0477	--
Compr. Index, C_c	3.144				3.825			
Coeff. Secondary Comp, C_α (cm)	0.1735				0.1943			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-1. Experimental Results, Anaerobic, Stage I (Continue 3)

Beaker[a]	M				N			
Date (Duration, Days)	December 27, 1977 (0)				December 28, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.42	11.54	10.01	--	13.93	11.63	10.14	--
Coeff. Consol., c_v (cm^2/sec)	1.631	.8959	.5919	--	1.483	.9366	.5682	--
Equiv. Liq. Limit[b], LL (%)	656	656	656	--	659	659	659	--
Permeability, k (cm/sec)	.02314	.00718	.00346	--	.01979	.00697	.00304	--
Coeff. Comp., av (cm^2/gm)	.1738	.0865	.0578	--	.16012	.07972	.05322	--
Compr. Index, C_c	4.636				4.272			
Coeff. Secondary Comp, C_α (cm)	0.2411				0.2531			
Beaker[a]	O				P			
Date (Duration, Days)	December 29, 1977 (0)				December 30, 1977 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.68	11.13	9.81	--	12.47	10.99	9.93	--
Coeff. Consol., c_v (cm^2/sec)	3.295	1.750	1.163	--	1.816	1.108	.7109	--
Equiv. Liq. Limit[b], LL (%)	782	782	782	--	732	732	732	--
Permeability, k (cm/sec)	.03851	.01116	.00529	--	.02274	.00770	.00355	--
Coeff. Comp., av (cm^2/gm)	.1601	.0797	.0532	--	.1653	.0823	.0549	--
Compr. Index, C_c	4.044				4.409			
Coeff. Secondary Comp, C_α (cm)	0.1454				0.2171			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-1. Experimental Results, Anaerobic, Stage I (Continue 4)

Beaker[a]	Q				R			
Date (Duration, Days)	December 31, 1977 (0)				January 1, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.60	11.20	9.80	--	11.96	10.39	9.25	--
Coeff. Consol., c_v (cm^2/sec)	3.117	1.339	.8696	--	2.497	1.261	1.140	--
Equiv. Liq. Limit[b], LL (%)	846	846	846	--	820	820	820	--
Permeability, k (cm/sec)	.03955	.00939	.00438	--	.02867	.00779	.00508	--
Coeff. Comp., av (cm^2/gm)	.1916	.0954	.0637	--	.1688	.0840	.0561	--
Compr. Index, C_c	5.111				4.502			
Coeff. Secondary Comp, C_α (cm)	0.1828				0.1777			
Beaker[a]	13				14			
Date (Duration, Days)	January 14, 1978 (0)				January 15, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.46	10.03	8.84	--	11.99	10.54	9.55	--
Coeff. Consol., c_v (cm^2/sec)	.7824	.4161	.2280	--	.5075	.3731	.1581	--
Equiv. Liq. Limit[b], LL (%)	320	320	320	--	--	--	--	--
Permeability, k (cm/sec)	.01291	.00387	.00157	--	.00874	.00367	.00115	--
Coeff. Comp., av (cm^2/gm)	.1419	.0706	.0472	--	.1601	.0797	.0532	--
Compr. Index, C_c	3.786				4.272			
Coeff. Secondary Comp, C_α (cm)	0.2606				0.2510			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-1. Experimental Results, Anaerobic, Stage I (Continue 5)

Beaker[a]	15				16			
Date (Duration, Days)	January 16, 1978 (0)				January 17, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.94	11.23	10.41	--	11.40	10.77	9.75	--
Coeff. Consol., c_v (cm^2/sec)	2.616	2.096	1.266	--	2.386	1.924	1.341	--
Equiv. Liq. Limit[b], LL (%)	650	650	650	--	622	622	622	--
Permeability, k (cm/sec)	.03716	.01583	.00691	--	.0363	.0159	.0080	--
Coeff. Comp., av (cm^2/gm)	.1790	.0891	.0595	--	.1840	.0916	.0611	--
Compr. Index, C_c	4.775				4.908			
Coeff. Secondary Comp, C_α (cm)	0.2520				0.2302			
Beaker[a]	17				18			
Date (Duration, Days)	January 18, 1978 (0)				January 19, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.73	10.24	9.47	--	11.23	10.72	9.98	--
Coeff. Consol., c_v (cm^2/sec)	3.668	2.215	1.839	--	2.923	2.255	2.045	--
Equiv. Liq. Limit[b], LL (%)	758	758	758	--	--	--	--	--
Permeability, k (cm/sec)	.03628	.01846	.01114	--	.04241	.01778	.01165	--
Coeff. Comp., av (cm^2/gm)	.1858	.0925	.0618	--	.2202	.1096	.0732	--
Compr. Index, C_c	4.958				5.876			
Coeff. Secondary Comp, C_α (cm)	0.1852				0.1829			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-2. Experimental Results, Aerobic, Stage I.

Beaker[a]	1				2			
Date (Duration, Days)	January 2, 1978 (0)				January 3, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.34	12.01	11.14	--	12.04	11.12	10.61	--
Coeff. Consol., c_v (cm^2/sec)	.7452	.5656	.2046	--	1.375	.8946	.942	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.00658	.00258	.00065	--	.01288	.00425	.00307	--
Coeff. Comp., av (cm^2/gm)	.0563	.0280	.0187	--	.0548	.0273	.0182	--
Compr. Index, C_c	1.502				1.462			
Coeff. Secondary Comp, C_α (cm)	0.1747				.1285			
Beaker[a]	3				4			
Date (Duration, Days)	January 4, 1978 (0)				January 5, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	10.92	10.59	10.23	--	10.92	10.64	10.39	--
Coeff. Consol., c_v (cm^2/sec)	.7301	.4634	.3355	--	.7495	.6269	.4513	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.00439	.00141	.00070	--	.00488	.00207	.00103	--
Coeff. Comp., av (cm^2/gm)	.0352	.0175	.0117	--	.0379	.0188	.0126	--
Compr. Index, C_c	0.939				1.010			
Coeff. Secondary Comp, C_α (cm)	0.0867				0.1277			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-2. Experimental Results, Aerobic, Stage I (Continue 1)

Beaker[a]	5				6			
Date (Duration, Days)	January 6, 1978 (0)				January 7, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.00	12.79	11.85	--	13.21	12.65	12.14	--
Coeff. Consol., c_v (cm^2/sec)	1.123	.9034	.4753	--	0.9634	.9419	.7204	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.01008	.00419	.00153	--	.00684	.00344	.00182	--
Coeff. Comp., av (cm^2/gm)	.0797	.0397	.0265	--	.0639	.0318	.0212	--
Compr. Index, C_c	2.126				1.704			
Coeff. Secondary Comp, C_α (cm)	0.1576				0.1559			
Beaker[a]	7				8			
Date (Duration, Days)	January 8, 1978 (0)				January 9, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.49	11.86	11.43	--	11.73	11.40	10.95	--
Coeff. Consol., c_v (cm^2/sec)	0.9806	.6882	.7215	--	1.245	0.6366	.5860	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.00793	.00286	.00208	--	.00799	.00208	.00132	--
Coeff. Comp., av (cm^2/gm)	.0681	.0339	.0226	--	.0507	.0252	.0168	--
Compr. Index, C_c	1.816				1.352			
Coeff. Secondary Comp, C_α (cm)	0.1253				0.1142			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-2. Experimental Results, Aerobic, Stage I (Continue 2)

Beaker[a]	9				10			
Date (Duration, Days)	January 10, 1978 (0)				January 11, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.13	12.78	12.14	--	10.36	9.80	9.35	--
Coeff. Consol., c_v (cm^2/sec)	1.206	.7978	.5484	--	.7516	0.5000	.2441	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.01694	.00578	.00273	--	.00627	.00217	.00074	--
Coeff. Comp., av (cm^2/gm)	.1121	.0558	.0372	--	.0741	.0369	.0246	--
Compr. Index, C_c	2.990				1.978			
Coeff. Secondary Comp, C_α (cm)	0.2149				0.1213			
Beaker[a]	11				12			
Date (Duration, Days)	January 12, 1978 (0)				January 13, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.17	10.67	10.23	--	9.85	9.49	8.78	--
Coeff. Consol., c_v (cm^2/sec)	.5452	.4452	.4333	--	.7527	.3731	.3366	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	.00325	.00137	.00091	--	.01065	.00283	.00183	--
Coeff. Comp., av (cm^2/gm)	.0573	.0285	.0190	--	.1188	.0591	.0395	--
Compr. Index, C_c	1.528				3.169			
Coeff. Secondary Comp, C_α (cm)	0.0894				0.2215			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-3. Experimental Results, Anaerobic, Stage II.

Beaker[a]	A				B			
Date (Duration, Days)	February 13, 1978 (60)				February 14, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	10.87	9.78	8.66	--	9.25	8.36	7.49	--
Coeff. Consol., c_v (cm^2/sec)	.5462	.2000	.1355	--	.0414	.0473	.0226	--
Equiv. Liq. Limit[b], LL (%)	320	320	320	--	288	288	288	--
Permeability, k (cm/sec)	.00660	.00132	.00064	--	.00052	.00020	.00012	--
Coeff. Comp., av (cm^2/gm)	.1032	.0516	.0344	--	.1010	.0510	.0340	--
Compr. Index, C_c	2.76				2.71			
Coeff. Secondary Comp, C_α (cm)	0.1939				0.2647			
Beaker[a]	C				D			
Date (Duration, Days)	February 15, 1978 (60)				February 15, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	7.42	6.53	5.94	--	7.18	6.38	5.82	--
Coeff. Consol., c_v (cm^2/sec)	.0237	.0237	.0098	--	.0161	.0069	.0068	--
Equiv. Liq. Limit[b], LL (%)	216	216	216	--	193	193	193	--
Permeability, k (cm/sec)	.00026	.00014	.00004	--	.00017	.00007	.00005	--
Coeff. Comp., av (cm^2/gm)	.07660	.0383	.0256	--	.1092	.0546	.0364	--
Compr. Index, C_c	2.05				2.92			
Coeff. Secondary Comp, C_α (cm)	0.1064				0.2804			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-3. Experimental Results, Anaerobic, Stage II (Continue 1)

Beaker[a]	G				H			
Date (Duration, Days)	February 19, 1978 (60)				February 20, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.85	11.41	9.93	--	8.69	8.20	7.74	--
Coeff. Consol., c_v (cm^2/sec)	.9978	.3591	.3323	--	.0215	.0133	.0068	--
Equiv. Liq. Limit[b], LL (%)	742	742	742	--	577	577	577	--
Permeability, k (cm/sec)	.01122	.00229	.00154	--	.00033	.00012	.00004	--
Coeff. Comp., av (cm^2/gm)	.1757	.0879	.0586	--	.2082	.1041	.0694	--
Compr. Index, C_c	4.70				5.57			
Coeff. Secondary Comp, C_α (cm)	0.2718				0.2741			
Beaker[a]	M				N			
Date (Duration, Days)	February 25, 1978 (60)				February 26, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.19	10.54	9.25	--	8.84	7.36	6.25	--
Coeff. Consol., c_v (cm^2/sec)	1.167	.4968	.4828	--	.1452	.1925	.0849	--
Equiv. Liq. Limit[b], LL (%)	1280	1280	1280	--	1158	1158	1158	--
Permeability, k (cm/sec)	.0148	.0035	.0024	--	.0021	.0016	.0005	
Coeff. Comp., av (cm^2/gm)	.3148	.1574	.1049	--	.3230	.1615	.1076	
Compr. Index, C_c	8.42				8.64			
Coeff. Secondary Comp, C_α (cm)	0.2266				0.1763			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

*Beakers E, F, I, J, K, L,), P, Q, R were not tested (insufficient material)

TABLE G-3. Experimental Results, Anaerobic, Stage II (Continue 2)

Beaker[a]	13				14			
Date (Duration, Days)	March 15, 1978 (60)				March 16, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.13	9.91	8.74	--	9.96	8.59	7.44	--
Coeff. Consol., c_v (cm^2/sec)	1.367	.9645	.2839	--	0.6312	.3989	.1667	--
Equiv. Liq. Limit[b], LL (%)	340	340	340	--	278	278	278	--
Permeability, k (cm/sec)	.02317	.00927	.00202	--	.01193	.00443	.00112	--
Coeff. Comp., av (cm^2/gm)	.1346	.0673	.0449	--	.1559	.0779	.0520	--
Compr. Index, C_c	3.60				4.17			
Coeff. Secondary Comp, C_α (cm)	0.1923				0.2550			
Beaker[a]	15				16			
Date (Duration, Days)	March 17, 1978 (60)				March 18, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.83	11.74	10.36	--	11.58	10.44	9.07	--
Coeff. Consol., c_v (cm^2/sec)	1.918	1.222	.8000	--	1.898	.7849	.1860	--
Equiv. Liq. Limit[b], LL (%)	636	626	626	--	770	770	770	--
Permeability, k (cm/sec)	.03002	.01082	.00518	--	.03907	.00923	.00163	--
Coeff. Comp., av (cm^2/gm)	.1951	.0976	.0651	--	.3402	.1701	.1134	--
Compr. Index, C_c	5.22				9.10			
Coeff. Secondary Comp, C_α (cm)	0.2004				0.2098			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-3. Experimental Results, Anaerobic, Stage II (Continue 3)

Beaker[a]	17				18			
Date (Duration, Days)	March 19, 1978 (60)				March 20, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.13	11.96	10.77	--	11.07	9.75	8.31	--
Coeff. Consol., c_v (cm^2/sec)	3.169	3.167	2.027	--	1.966	.7720	.3376	--
Equiv. Liq. Limit[b], LL (%)	1136	1136	1136	--	1600	1600	1600	--
Permeability, k (cm/sec)	.04283	.02417	.01103	--	.04365	.01018	.00340	--
Coeff. Comp., av (cm^2/gm)	.2557	.1278	.0853	--	.6560	.3280	.2190	--
Compr. Index, C_c	6.84				17.55			
Coeff. Secondary Comp, C_α (cm)	0.1458				0.2187			
Beaker[a]								
Date (Duration, Days)								
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)								
Coeff. Consol., c_v (cm^2/sec)								
Equiv. Liq. Limit[b], LL (%)								
Permeability, k (cm/sec)								
Coeff. Comp., av (cm^2/gm)								
Compr. Index, C_c								
Coeff. Secondary Comp, C_α (cm)								

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-4. Experimental Results, Aerobic, Stage II.

Beaker[a]	1				2			
Date (Duration, Days)	March 3, 1978 (60)				March 4, 1978 (60)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	8.84	8.26	7.49	--	7.37	6.09	5.64	--
Coeff. Consol., c_v (cm^2/sec)	.0161	.0133	.0037	--	.0010	.0008	.0020	--
Equiv. Liq. Limit[b], LL (%)	162	162	162	--	122	122	122	--
Permeability, k (cm/sec)	.00026	.00012	.00002	--	.00002	.00001	.00002	--
Coeff. Comp., av (cm^2/gm)	.0766	.0383	.0256	--	.0740	.0370	.0247	--
Compr. Index, C_c	2.05				1.98			
Coeff. Secondary Comp, C_α (cm)	0.4178				0.3355			
Beaker[a]	4							
Date (Duration, Days)	March 5, 1978 (60)							
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	6.53	5.12	5.64	--				
Coeff. Consol., c_v (cm^2/sec)	.0046	.0028	.0062	--				
Equiv. Liq. Limit[b], LL (%)	132	132	132	--				
Permeability, k (cm/sec)	.000034	.000011	.000018	--				
Coeff. Comp., av (cm^2/gm)	.0347	.0174	.0116	00				
Compr. Index, C_c	0.93							
Coeff. Secondary Comp, C_α (cm)	0.2162							

[a]See Table A-1 for sample composition.

[b]See Section for definition.

*Beakers 5, 6, 7, 8, 9, 10, 11, and 12 were not tested (insufficient material)

TABLE G-5. Experimental Results, Anaerobic Stage III-0 through III-7.

Beaker[a]	A_1*				A_5			
Date (Duration, Days)	April 4, 1978 (0)				July 3, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	11.66	10.29	9.30	8.66	12.04	10.79	9.63	8.79
Coeff. Consol., c_v (cm^2/sec)	.2753	.2710	.1677	.0774	.4150	.3064	.1559	.0839
Equiv. Liq. Limit[b], LL (%)	365	365	365	365	379	379	379	379
Permeability, k (cm/sec)	.00360	.00198	.00088	.00032	.00563	.00234	.00088	.00038
Coeff. Comp., av (cm^2/gm)	0.1072	.0536	.0348	.0268	.1154	.0575	.0384	.0288
Compr. Index, C_c	2.87				3.08			
Coeff. Secondary Comp, C_α (cm)	0.2291				0.3061			
Beaker[a]	B_1*				B_5			
Date (Duration, Days)	April 5, 1978 (0)				July 4, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.95	12.09	11.07	10.34	12.32	11.61	10.54	9.78
Coeff. Consol., c_v (cm^2/sec)	1.303	.9548	.5989	.5226	1.151	1.094	.6708	.5622
Equiv. Liq. Limit[b], LL (%)	678	678	678	678	720	720	720	720
Permeability, k (cm/sec)	.01822	.00735	.00330	.00228	.01805	.00947	.00421	.00283
Coeff. Comp., av (cm^2/gm)	.1787	.0893	.0596	.0447	.1915	.0954	.0637	.0478
Compr. Index, C_c	4.78				5.11			
Coeff. Secondary Comp, C_α (cm)	0.2230				0.2459			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 1)

Beaker[a]	C_1*				C_5			
Date (Duration, Days)	April 6, 1978 (0)				July 5, 1978 (0)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.55	11.79	10.85	10.11	12.40	11.25	10.34	9.80
Coeff. Consol., c_v (cm^2/sec)	1.314	1.021	.7376	.5860	1.763	1.061	.8374	.2655
Equiv. Liq. Limit[b], LL (%)	940	940	940	940	947	947	947	947
Permeability, k (cm/sec)	.01898	.00790	.00418	.00267	.02413	.00796	.00445	.00113
Coeff. Comp., av (cm^2/gm)	.2292	.1146	.0764	.0573	.2046	.1019	.0680	.0511
Compr. Index, C_c	6.13				5.46			
Coeff. Secondary Comp, C_α (cm)	0.2540				0.2413			
Beaker[a]	A_1*				A_5			
Date (Duration, Days)	April 11, 1978 (7)				July 10, 1978 (7)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.07	10.85	9.58	8.66	11.02	10.13	9.37	8.81
Coeff. Consol., c_v (cm^2/sec)	.4667	.4871	.1548	.0699	.4096	.6138	.1215	.0475
Equiv. Liq. Limit[b], LL (%)	350	350	350	350	338	338	338	338
Permeability, k (cm/sec)	.00852	.00505	.00118	.00043	.00715	.00580	.00082	.00026
Coeff. Comp., av (cm^2/gm)	.1596	.0798	.0532	.0399	.1462	.0728	.0486	.0365
Compr. Index, C_c	4.27				3.90			
Coeff. Secondary Comp, C_α (cm)	0.3622				0.3719			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 2)

Beaker[a]	B_1*				B_5			
Date (Duration, Days)	April 12, 1978 (7)				July 11, 1978 (7)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.16	12.04	10.85	10.01	12.09	11.13	10.06	9.17
Coeff. Consol., c_v (cm^2/sec)	.8559	.7344	.4602	.2452	.8084	.6751	.4171	.2462
Equiv. Liq. Limit[b], LL (%)	688	688	688	688	693	693	693	693
Permeability, k (cm/sec)	.00266	.00732	.00330	.00142	.01550	.00722	.00325	.00158
Coeff. Comp., av (cm^2/gm)	.2370	.1190	.0790	.0590	.2541	.1265	.0845	.0634
Compr. Index, C_c	6.34				6.78			
Coeff. Secondary Comp, C_α (cm)	0.2783				0.2261			
Beaker[a]	C_1*				C_5			
Date (Duration, Days)	April 13, 1978 (7)				July 12, 1978 (7)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	13.18	11.79	10.49	9.58	11.79	10.52	9.39	8.53
Coeff. Consol., c_v (cm^2/sec)	.8312	.6054	.5086	.1720	.7654	.6504	.3849	.2849
Equiv. Liq. Limit[b], LL (%)	1045	1045	1045	1045	960	960	960	960
Permeability, k (cm/sec)	.01435	.00595	.00370	.00100	.01402	.00666	.00294	.00176
Coeff. Comp., av (cm^2/gm)	.2840	.1420	.0950	.0710	.2845	.1416	.0946	.0710
Compr. Index, C_c	7.61				7.59			
Coeff. Secondary Comp, C_α (cm)	0.2631				0.2469			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 3)

Beaker[a]	A_1*				A_5			
Date (Duration, Days)	April 18, 1978 (14)				July 17, 1978 (14)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.19	10.30	8.79	--	8.28	7.16	6.50	--
Coeff. Consol., c_v (cm^2/sec)	.0602	.0141	.0093	--	.0134	.0100	.0048	--
Equiv. Liq. Limit[b], LL (%)	325	325	325	--	367	367	367	--
Permeability, k (cm/sec)	.00134	.00019	.0003	--	.00024	.00010	.00003	--
Coeff. Comp., av (cm^2/gm)	.2290	.1146	.0764	--	.1229	.0612	.0409	--
Compr. Index, C_c	6.13				3.28			
Coeff. Secondary Comp, C_α (cm)	0.7335				0.3520			
Beaker[a]	B_1*				B_5			
Date (Duration, Days)	April 19, 1978 (14)				July 18, 1978 (14)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.55	10.77	9.02	7.90	9.19	8.13	6.91	6.17
Coeff. Consol., c_v (cm^2/sec)	.0892	.0925	.0258	.0197	.1172	.0888	.0325	.0192
Equiv. Liq. Limit[b], LL (%)	588	588	588	588	588	588	588	588
Permeability, k (cm/sec)	.00212	.00131	.00028	.00010	.00274	.00123	.00034	.00017
Coeff. Comp., av (cm^2/gm)	.3133	.1566	.1045	.0783	.2976	.1482	.0989	.0742
Compr. Index, C_c	8.38				7.94			
Coeff. Secondary Comp, C_α (cm)	0.4476				0.3505			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 4)

Beaker[a]	C_1*				C_5			
Date (Duration, Days)	April 20, 1978 (14)				July 19, 1978 (14)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	--	8.13	6.99	6.51	9.30	7.80	6.58	5.82
Coeff. Consol., c_v (cm^2/sec)	--	.0559	.0269	.0118	.2774	.1172	.0779	.0344
Equiv. Liq. Limit[b], LL (%)	--	863	863	863	915	915	915	915
Permeability, k (cm/sec)	--	.00089	.00036	.00013	.00630	.00162	.00083	.00030
Coeff. Comp., av (cm^2/gm)	--	.2019	.1346	.1009	.3823	.1903	.1271	.0954
Compr. Index, C_c	10.80				10.20			
Coeff. Secondary Comp, C_α (cm)	0.4298				0.3188			
Beaker[a]	A_2				B_2			
Date (Duration, Days)	April 25, 1978 (21)				April 26, 1978 (21)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	12.78	12.07	11.61	--	11.58	10.01	8.79	--
Coeff. Consol., c_v (cm^2/sec)	.0366	.0161	.0215	--	.0140	.0237	.0078	--
Equiv. Liq. Limit[b], LL (%)	411	411	411	--	525	525	525	--
Permeability, k (cm/sec)	.00028	.00007	.00006	--	.00036	.00034	.00009	--
Coeff. Comp., av (cm^2/gm)	.0847	.0422	.0282	--	.3523	.1754	.1171	--
Compr. Index, C_c	2.26				9.40			
Coeff. Secondary Comp, C_α (cm)	0.1803				0.6532			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 5)

Beaker[a]	C_2				A_2			
Date (Duration, Days)	April 27, 1978 (21)				May 9, 1978 (35)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	9.68	7.39	5.74	--	10.24	9.73	9.27	--
Coeff. Consol., c_v (cm^2/sec)	.0065	.0022	.0011	--	.0026	.0015	.0026	--
Equiv. Liq. Limit[b], LL (%)	743	743	743	--	312	312	312	--
Permeability, k (cm/sec)	--	.00004	.00002	--	.00002	.00001	.00001	--
Coeff. Comp., av (cm^2/gm)	.4753	.2366	.1580	--	.0648	.0323	.0216	--
Compr. Index, C_c	12.68				1.73			
Coeff. Secondary Comp, C_α (cm)	0.6927				0.2321			
Beaker[a]	B_1				C_4			
Date (Duration, Days)	May 10, 1978 (35)				May 11, 1978 (35)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	6.86	5.54	4.90	--	7.04	6.09	5.41	--
Coeff. Consol., c_v (cm^2/sec)	.0014	.0022	.0017	--	.0060	.0037	.0023	--
Equiv. Liq. Limit[b], LL (%)	400	400	400	--	598	598	598	--
Permeability, k (cm/sec)	.00001	.00002	.00001	--	.00010	.00003	.00002	--
Coeff. Comp., av (cm^2/gm)	.1409	.0702	.0468	--	.2223	.1107	.0739	--
Compr. Index, C_c	3.76				5.93			
Coeff. Secondary Comp, C_α (cm)	0.0598				0.2009			

[a]See Table A-1 for sample composition.

[b]See Section for definition.

TABLE G-5. Experimental Results, Anaerobic, Stage III-0 through III-7. (Continue 6)

Beaker[a]	A_4				B_4			
Date (Duration, Days)	May 23, 1978 (49)				May 24, 1978 (49)			
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	--	--	--	--	5.26	4.67	4.50	--
Coeff. Consol., c_v (cm^2/sec)	--	--	--	--	.0039	.0033	.0024	--
Equiv. Liq. Limit[b], LL (%)	--	--	--	--	--	--	--	--
Permeability, k (cm/sec)	--	--	--	--	.00005	.00002	.00001	--
Coeff. Comp., av (cm^2/gm)	--	--	--	--	.1019	.0508	.0339	--
Compr. Index, C_c	--				2.72			
Coeff. Secondary Comp, C_α (cm)	--				0.5098			
Beaker[a]	C_2							
Date (Duration, Days)	May 25, 1978 (49)							
Consol. Press, σ_c (gm/cm^2)	11.6	23.3	34.9	46.5	11.6	23.3	34.9	46.5
Avg. Height, $H_{avg.}$ (cm)	4.78	4.24	3.73	--				
Coeff. Consol., c_v (cm^2/sec)	.0019	.0013	.0011	--				
Equiv. Liq. Limit[b], LL (%)	--	--	--	--				
Permeability, k (cm/sec)	.00003	.00001	.00001	--				
Coeff. Comp., av (cm^2/gm)	.1540	.0767	.0512	--				
Compr. Index, C_c	4.11							
Coeff. Secondary Comp, C_α (cm)	0.1965							

[a]See Table A-1 for sample composition.

[b]See Section for definition.