INVESTIGATION OF THE STRUCTURE AND SHEAR STRENGTH CHARACTERISTICS OF A CLAY SOIL

Thesis for the Degree of M. S.

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Roger David Goughnour

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This is to certify that the

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Investigation of the Structure and Shear Strength Characteristics of a Clay Soil

presented by

Roger David Goughnour

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of the requirements for

M. S. degree in Civil Engineering

[signature]
Major professor

Date Sept 29, 1961

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INVESTIGATION OF THE STRUCTURE AND SHEAR STRENGTH CHARACTERISTICS OF A CLAY SOIL

by

Roger David Goughnour

AN ABSTRACT

Submitted to the College of Engineering
Michigan State University of Agriculture and
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the requirements for the degree of

MASTER OF SCIENCE

Department of Civil and Sanitary Engineering

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Approved: ________________________________

ROGER DAVID GOUGHNOUR ABSTRACT

This thesis is an investigation of the strength and structural differences occurring between flocculated and remolded clays.

The orientation of clay particles of flocculated and remolded samples were studied by x-ray diffraction. A method of freeze-drying was used in the preparation of the samples. The shear strength was studied by means of triaxial tests.

The x-ray diffraction studies showed a random particle orientation in the flocculated clays. Clays which were highly consolidated showed a high degree of particle orientation. Remolded samples showed orientation over small areas, but the direction of orientation changes from one place to another.

The triaxial test showed that the cohesion of the remolded clay acts much as a viscous liquid, while the cohesion of the flocculated clay acts as a brittle bond.

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I. DEVELOPMENT OF CURRENT KNOWLEDGE

Soil Structure

The importance of the structure of cohesive soils on the strength properties has been recognized by soil engineers for more than thirty years. Until about 1925, cohesion was thought to be caused by some hypothetical amorphous substance. In 1925, Karl Terzaghi discredited this theory with a paper on the structure and bonds in cohesive soils. He stated that cohesive soil has a structure similar to a honeycomb, with large amounts of water being held within the voids and the cohesion was caused by attractive forces between adjacent soil particles.

In 1926, Goldschmidt performed a series of experiments with mixtures of clay minerals and various liquids. He found that with non-polar liquids, the clay lost its plasticity and behaved only as a frictional material. He concluded that the plasticity of clays was dependent on a combination of both the mineral and the liquid. He proposed that the crystalline minerals were surrounded by a film of adsorbed water molecules and that the water molecules stick to each other and to the minerals because of their dipole moment. He introduced the term "cardhouse" structure to describe the arrangement of the flaky minerals in highly sensitive clays. This structure is similar to that presented in Figures 1a and 1b. The surplus water was considered by Goldschmidt as being enclosed in the space between the mineral flakes. The less the sensitivity of the clay, the more dense the arrangement of the particles.

Observations of the structure of sensitive clays have been made with the petrographic microscope (Mitchell, 1956) and the electron microscope (Rosenqvist, 1959). These observations tend to substantiate the cardhouse structure.

Forces Acting Between Soil Particles

The forces acting between soil particles may be divided into attractive and repulsive forces. The attractive forces include van der Waals' forces, Coulombic forces, water dipole linkages, and hydrogen and ionic bonds. The repulsive forces are primarily due to repulsion between like electrical charges.

Because of isomorphous substitution* occurring within the mineral lattice, the individual clay crystals carry a net negative electrical charge. This net negative charge is balanced by positive ions near the surface of the minerals. Water may also be attached to this negatively charged surface due to the dipolar nature of the water molecules. Figures 2a and 2b show possible conditions under which attractive forces

*Isomorphous substition occurs when a metallic ion in the lattice of the perfect clay crystal is replaced in the same position with an ion of similar properties but lower valence.

may exist because of cations and water molecules (Lambe, 1958).

The edge of clay plates are believed to be positively charged (Lambe, 1958). Thus, a surface to edge relation will give an attractive force.

The main reason for repulsion of clay particles is due to the like negative charge on the surface of the particles. Also, when two particles with cations are brought together, a repulsion will take place as shown in Figure 2c.

When the attractive forces of a clay suspension exceed the repulsive forces, the clay flocculates. The positive edge attracted to the negative surface results in a random particle orientation. This is demonstrated by the cardhouse structure of Lambe shown in Figure 1b. As a result of this, the flocculated soil has a higher void ratio at a given consolidation pressure, than a non-flocculated soil. It is also possible to obtain a parallel orientation in a flocculated clay by the addition of an electrolyte. By adding a salt to the clay-water system, a high concentration of anions will gather at the edges of the particles. This reduces the positive edge charge as well as the repulsive force and permits parallel orientation as shown in Figure 1a.

Effect Of Remolding

Nearly all sedimentary clays lose strength when worked or remolded. Mitchell (1956) has shown the greater the orientation improvement (changing from a random to a parallel arrangement) with remolding, the greater the loss in strength. The magnitude of this loss is indicated by "sensitivity" which is defined as the ratio of the strength of the undisturbed to the completely remolded soil. When a flocculated soil is remolded, the edge to surface contact is broken and a loss of strength results. At the same time, the particle orientation is improved as shown in Figure 1c.

Shear Strength

The shear strength of a soil is influenced to a very large extent by the attractive and repulsive forces, which in turn depend upon the particle spacing, particle orientation and the structure.

The importance of the structure, according to Lambe (1958) is illustrated in Figures 3a and 3b. They show two adjacent clay particles with the same average spacing Δ . The sum of the contact pressure and the net attractive force between two particles varys with the power function of the spacing*. Thus, tilting the two particles from a parallel position to the position shown in Figure 3b, results in a greater increase in the attractive force on the right side than is lost on the left side. Therefore, the shear stress required to slide the particles relative to each other is greater in Figure 3b than in 3a. By the same reasoning, if the particles are flocculated in a perpendicular position

*See Lambe (1953 or 1958) for a discussion of quantitative interparticle forces.

as shown in Figure 3c, they possess a higher resistance to displacement than the parallel particles of Figure 3d. In short, for a given average particle spacing, the more nearly parallel the adjacent particles, the lower the shearing resistance.

The shear strength of soils is usually considered to be made up of cohesion and friction. Cohesion is the shearing resistance between two particles which exists independently of external forces. In the flocculant clays shown in Figures 1b and 3c, cohesion exists at the edge to plate contacts. Lambe (1958) suggested that cohesion is mainly electrostatic attraction between the negative plate charge and the positive edge charge.

The friction may be due to both electrical forces and physical interference between particles during shear displacements. The maximum shear resistance due to friction is a direct function of the force acting normal to the plane of shear. A clean sand is an example of a material with only the frictional type of strength.

II. OBJECTIVE OF PRESENT STUDY

The primary objective of this study was to evaluate the strength and structural differences occurring between flocculated and remolded clays. The orientation of clay particles of flocculated and remolded samples was studied by x-ray diffraction. The shear strength was studied by means of triaxial tests.

III. SOIL STUDIED

The clay used in this investigation is a glacial lake clay from a site about 15 miles south of Sault Ste. Marie, Michigan. It is composed of about 60% clay and 40% silt. X-ray diffraction studies on the clay fraction showed approximately equal percentages of illite, vermiculite and chlorite. The soil has a flocculant structure with a sensitivity of 8 in the natural state. It was found that the clay could be flocculated in the laboratory, and that it would retain its flocculent state upon consolidation. Other characteristics of this soil are summarized in table I.

IV. X-RAY STUDIES

Use Of The Flat Plate Camera

A diagram of the flat plate x-ray camera is shown in Figure 4. Use is made of Braggs law to understand the mechanics of the flat plate camera. Braggs law may be stated as:

$$n\lambda = 2d\sin\theta \quad \text{or} \quad d = \frac{n\lambda}{2\sin\theta}$$

It states that the distance (d) between parallel planes, for a first order reflection (n=1), is equal to the wave length (λ) divided by two times the sine of the angle θ. Figure 5 illustrates the use of this principle. It can be seen that the reflection of the x-ray beam depends on a plane of a crystal being at the angle θ to the x-ray beam. When a powder specimen is used, the planes are arranged in an entirely random manner. There should be enough particles turned at the angle θ to the incident primary beam of x-rays to produce a continuous reflection. The reflection from a beam passing through a powder specimen forms a series of circular cones. On a photographic plate it is shown as a series of concentric rings with uniform intensity. Each ring corresponds to one set of planes of spacing d.

If instead of a powder, a clay with preferred orientation in one direction (Figure 1c) is used, reflection occurs only on the plane parallel to the orientation of the clay particle. On the photographic plane, the reflected rays are concentrated into points or short arcs instead of being distributed evenly along a circle. Thus, by observing the length of the arc of the reflected beam, it is possible to obtain an estimate of the particle orientation of the clay.

Copper radiation ($\lambda = 1.539$ A°) was used to produce the x-rays in this investigation.

Use Of The Goniometer

The goniometer works on much the same principle as the flat plate camera. The only difference is that instead of a photographic plate, a counter is used in a preselected plane. The specimen is stationary while the counter is rotated about the specimen. A recorder records both the angle 2θ and the intensity of the reflected x-ray beam. If the crystals are completely parallel, the goniometer will produce sharp peaks at the angles corresponding to the interplanar distance spacings. As the degree of orientation decreases, the peaks will broaden and become less intense. Thus, it is possible to obtain an idea of the orientation of the clay along the plane selected.

The x-ray beam of the goniometer will penetrate through only a few particle layers of the specimen. This makes it necessary to obtain a sample with a surface which is both smooth and undisturbed. This condition is difficult to obtain and it limits the use of the goniometer for a quantitative analysis of particle orientation.

Preparation Of Specimens

The flat plate camera requires very thin specimens and an exposure of several hours. If a clay is left in a moist condition, it will dry out during the x-ray exposure. It is also impossible to obtain a thin specimen from a moist sample. A method of freeze drying was used to eliminate these difficulties. Specimens of approximately 2 square centimeters were immersed in liquid air, which results in rapid freezing of the clay. The specimens were then placed in a vacuum desicator under a vacuum. The desicator was kept at temperatures well below freezing until the specimens were dry. Rosenqvist (1959) found that the freezing in liquid air involves a very slight volume increase (3% for saturated samples), whereas the drying took place without any noticeable change in dimensions. For this reason, the mineral arrangement is assumed to be essentially the same before and after freeze drying. The dried samples were broken mechanically and thin specimens were obtained for analysis.

Results With The Flat Plate Camera

The soil used is composed of illite, chlorite, vermiculite and quartz. The chlorite and vermiculite have first order lattice spacings of 14 A° and second order spacings of 7 A°. The illite has a first order spacing of 10 A°. The quartz has a spacing of 3.3 A°. These are the most significant spacings.

Figure 6a is a powder pattern of the soil. The 14, 10 and 7 A° spacings are present though not too intense. It should be noted that each ring is uniformly intense throughout.

Figure 6b shows the pattern from a specimen obtained by placing a suspension of the soil in an evaporating dish and drying it out to a thin film. The particles in this thin film were very well oriented and were used as a base of comparison with other samples. The 14, 10 and 7 A° spacings appear as arcs which are parallel to the particle orientation. The arcs have much greater intensity than the rings of the powder pattern. The 3.3 A° quartz spacing still appears as a complete ring. This is because quartz is made up of irregular grains which do not orient. In Figure 1, the quartz is represented by the large, non-plate shaped particles.

Figures 6c and 6d represent patterns from a soil that was flocculated and then consolidated to a pressure of 0.35 kg/cm^2. These two figures represent the two extremes of orientation that can be obtained in this soil. Figure 6c is much the same as that obtained for the powder pattern. This would indicate that there is practically no orientation. Figure 6d represents some orientation, but not nearly as much as given in Figure 6b. It is probable that as pressure is applied to flocculated clay, there is local breakdown in the cardhouse structure. Thus, Figure 6c shows the clay still retaining the flocculated structure, while Figure 6d shows some breakdown of the structure.

Figure 6e was obtained from a soil consolidated to the high pressure of 40 kg/cm^2. This pattern is similar to that given in Figure 6b. It was also possible to find areas of slightly less orientation. This would tend to support the assumption illustrated in Figure 1c, in which an overall orientation exists with local areas of slightly less orientation.

X-ray diffraction studies were also run on a remolded sample which was hydrostatically consolidated to a pressure of 2.25 kg/cm^2. Some orientation could be found in local areas of this sample. The orientation shifted from one direction to another, with no one plane of preferred orientaion. Thus, as the sample was remolded and hydrostatically consolidated, the the clay particles were pushed closer together and local areas of orientaion developed.

Results With The Goniometer

Figure 7 represents the x-ray diffraction pattern obtained from the goniometer. The sample for Figure 7a was obtained as follows. A suspension of the clay was placed on a porous plate. A vacuum was applied to the plate and the excess water was drawn off, leaving a film of highly oriented clay on the plate. The diffraction pattern shows distinct peaks at 14, 10, 7 and 3.3 A° spacings.

Figure 7b is the pattern obtained on the horizontal plane of a soil consolidated to a pressure of 40 kg/cm^2. The distinct peaks of Figure 7a are not present, but instead there is a continuous intensity from about 15 A° to 6 A°. Thus, orientation is present, but not to the degree given in Figure 7a. The quartz peak of 3.3 A° is still present.

Figure 7c is the pattern obtained on the horizontal plane of a flocculated clay. There are no distinct peaks at 10 and 14 A° spacings which indicates that very little orientation is present.

The difference between the goniometer pattern of the highly oriented and the non-oriented samples is obvious. However, the fact that the diffraction surfaces are not perfectly smooth and undisturbed makes more exact work impossible.

V. TRIAXIAL TESTS

The triaxial tests were made on remolded and laboratory flocculated soil samples. Three consolidometers were specially constructed to prepare the flocculated samples. The consolidometers are made of two lucite tubes mounted on a six-inch diameter brass ring. The total height is 18 inches. A constant temperature box was built around the consolidometers to maintain a temperature of 26°C ±2° during sedimentation and consolidation.

About six inches of a dilute suspension of the soil (w=500% to 800%) was placed in the consolidometers and allowed to flocculate and settle. After a week, the clear liquid above the flocculated soil was drawn off and another six inches of the dilute suspension was added. Care was taken in adding the dilute suspension not to disturb the flocculated soil. This process was continued until the flocculated soil almost filled the consolidometers. A porous stone was then carefully lowered to the top of the clay and consolidation loading was begun. The first load increment was 0.002 kg/cm^2. This load was doubled each week (90%+ consolidation) until a final load of 0.35 kg/cm^2 was reached. The load was then removed and the consolidated soil allowed to rebound for three weeks. The soil cakes were then extruded from the brass rings and six 1.5 inch diameter by 3.0 inch triaxial specimens were prepared from each cake by hand trimming.

The soil cakes, when removed from the consolidometers, had a moisture content of about 60.0%. This is above the liquid limit of 55% and soil trimming was done very carefully so as not to disturb the sensitive structure which developes in the soil during sedimentation and consolidation. When this flocculant soil structure was disturbed, the remolded clay behaved like a viscous liquid.

Triaxial tests on the remolded samples were performed at Michigan State University by Mr. A. G. Douglas*. The results of these tests are included in the discussion of the results.

To obtain the remolded specimens, a batch of clay was prepared with an initial water content of approximately 38% and stored in the moist room. Specimens were molded from this material when needed.

Shear Strength Parameters

The shear stress τ_f at failure on any plane may be represented as (Terzaghi 1936 and Hvorslev 1937):

$$\tau_f = c_{ef} + (\sigma - u)_f \tan \phi_{ef}$$

in which σ is the normal stress on the plane and u is the pore water pressure. The subscript f denotes the values obtained at failure of the specimen. The parameters C_e and ϕ_e are known as Hvorslev's parameters and represent the

*Graduate Assistant, Michigan State University, (on leave from New South Wales, Australia "true cohesion" and the "true angle of friction" respectively. The true cohesion is dependent only on the void ratio (moisture content) at failure in saturated soils.

The measurement of Hvorselv's parameters by triaxial tests requires the results from at least two specimens with equal void ratios but different effective stresses at failure. This was achieved using the procedure outlined by Schmertman (1960). Three specimens were hydrostatically consolidated under a given pressure, σ_c . This pressure was then reduced on two of the specimens, one by 0.25 and the other by 0.50 kg/cm^2, resulting in one normally consolidated and two slightly overconsolidated specimens. Since a small reduction of pressure causes negligible swelling, the three specimens have almost identical void ratios. By using the same rate of strain on all specimens, and measuring the pore pressure during the tests, it was possible to determine the cohesion and friction at any strain during the tests. Schmertman's method was used on all of the triaxial tests of this report. Figure 9 illustrates the triaxial equipment used in these tests.

Constant Strain Rate Tests

The three specimens used for this test were first consolidated in the triaxial cells to a pressure of 2.00 kg/cm^2. After complete consolidation, the pressure was reduced on two of the samples, one by 0.25 kg/cm^2 and the other by 0.50 kg/cm^2. A pressure of 1.00 kg/cm^2 was added to both the chamber pressure and the pore pressure. This added pressure does not change the effective stress condition, but dissolves most of the air bubbles that may be present. and gives more accurate readings. After 24 hours, the constant strain rate was started. The pore pressure and the applied load were recorded continuously during the tests. The strain rate was 4% per hour computed for the initial specimen length of three inches. The deviator stress was computed by the method recommended by Lambe (1951). The decrease in area due to the consolidation was small and was not computed.

Friction and cohesion were obtained as shown in Figure 10. The results on the remolded clay are shown in Figure 10a and the flocculated clay in Figure 10b. For clearness, data from only two specimens are plotted. Figure 11 shows the deviator stress and the pore pressure as a function of the strain. Also shown in the Figure are the friction and the cohesion as a function of the strain.

Creep Tests

The specimens for the creep tests were prepared for testing in the same manner as the specimens for the constant-rate-of-strain tests. In the creep tests, each deviator stress increment is imposed on the specimen and maintained constant without drainage until the pore pressure comes to equilibrum. Then another increment is added to the deviator stress. This process is continued until the sample fails. In order to compute friction and cohesion at any time during the test, it is necessary to obtain almost identical strain-time relationships To achieve this, the deviator stress was varied on two of the samples by 0.25 and 0.50 kg/cm^2 to correspond to the differences in chamber pressures.

Figure 12 shows the determination of Hvorslev's parameters at different times for one load increment. Figure 12a represents the remolded clay and Figure 12b represents the flocculated clay. Figure 13 shows the change in friction and cohesion with time for both the remolded and flocculated clays. Figure 13 is typical for all loading increments except near the failure of the flocculated clay, On failure of the flocculated clay, the cohesion drops to zero while the angle of friction approaches $23.5°$(Figure 14).

Discussion Of Results

Figures 10 and 11 illustrate the two different types of failure occurring in flocculated and remolded clays. Figure 11 shows that for the remolded clay, the deviator stress builds up quickly at first and continues to increase at a constant rate at high strains. The pore pressure rises to a certain value and then remains almost constant. For the flocculated clays, the deviator stress builds up to a maximum value at low strains (2%) and then remains constant. The pore pressure continues to increase and levels off at about 10% strain. These results are shown in Figure 10a where the stress state of the remolded clay reaches the failure envelope quickly as the deviator stress increases. In Figure 10b, the stress state of the flocculated clay builds up until the deviator stress reaches a maximum value. The average normal stress then drops off with increasing pore pressure and reaches the failure envelope as the pore pressure becomes constant.

These results can be explained by considering the structure of the clay. The cardhouse structure of a flocculant clay makes it act much as a brittle material. The strength builds up rapidly, until the structure is broken. During this build up, the strength is composed only of cohesion. As the structure breaks down, the cohesion goes to zero and the specimen acts much as a frictional material. This would indicate that the cohesion is a result of the same interparticle forces which cause flocculation.

The fact that there is a high initial cohesion in the remolded clay would indicate that interparticle forces are also effective in these specimens. After the initial strength which is due to cohesion, the added strength is a result of friction.

It is noted that at large strains, cohesion is present in the remolded clays, while not measureable in the flocculated clays. This may be due to the difference in the final moisture contents (about 39% for the flocculated clay and 28% for the remolded clay). A consideration of the soil water system predicts that the interparticle forces have a diminishing effect with increasing moisture. As the moisture content increases, the distance between particles also increases, which reduces the net attractive forces.

The creep tests gave results similar to the constant-rate-of-strain tests. In Figures 12 and 13 it can be seen that most of the strength of the flocculated clay is due to cohesion. Most of this cohesion is still present after 24 hours, while there is little increase in friction. The flocculated clay fails at low strains (2%). As failure takes place and the cardhouse structure breaks down, the cohesion goes to zero while the angle of friction builds up to about 23.5°. In the remolded samples, the cohesion goes to zero within 24 hours after each load increment while the friction builds up to resist the load. The cohesion of the remolded clay may be compared to a viscous liquid. There is a strong resistance to each load increment, but this resistance goes to zero with time.

VI. CONCLUSIONS

X-Ray Studies

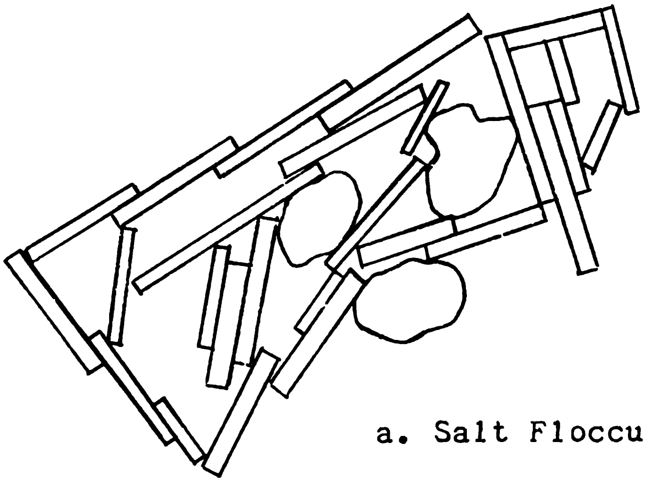
The flocculated clays, when consolidated to low pressures, showed no orientation to slight orientation. This was attributed to local break down of the structure as load was applied. It was also shown that a clay soil attains a high degree of orientation when it is consolidated to high pressures. The remolded samples showed areas of local orientation with a shifting from one plane to another. The results of this study are in agreement with the schematic representation of Lambe shown in Figure 1.

Triaxial Tests

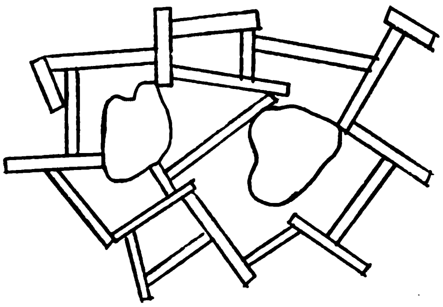
Both the constant-rate-of-strain tests and the creep tests yield results which are in agreement with the cardhouse structure theory.

In the remolded clay, the cohesion acts much as a viscous liquid. There is an initial high cohesion which becomes almost constant for a constant rate of strain and drops to zero for a constant load. The friction starts to build up immediately.

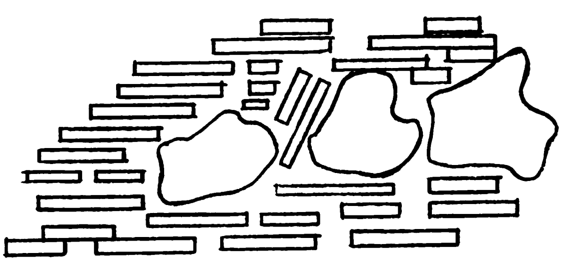
The flocculated clay, with the cardhouse structure, acts as a brittle material. There is a high strength at low strains due to cohesion. As the structure is broken with increased load, the cohesion drops off and the clay takes on the strength properties of the remolded clay. There is very little friction until this structure is broken.



a. Salt Flocculation



b. Non-Salt Flocculation



c. Consolidated

FIGURE 1 (after Lambe 1953, 1958)

SCHEMATIC REPRESENTATIONS OF PARTICLE ORIENTATION

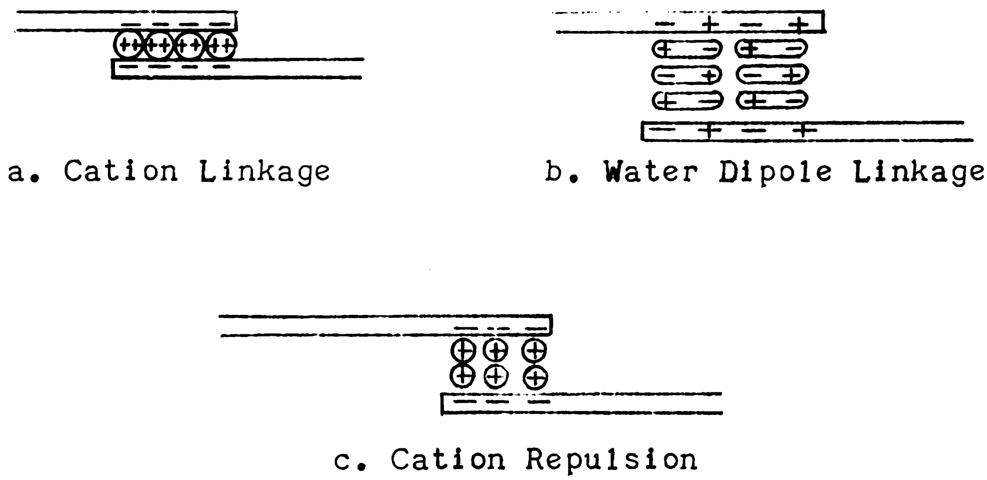
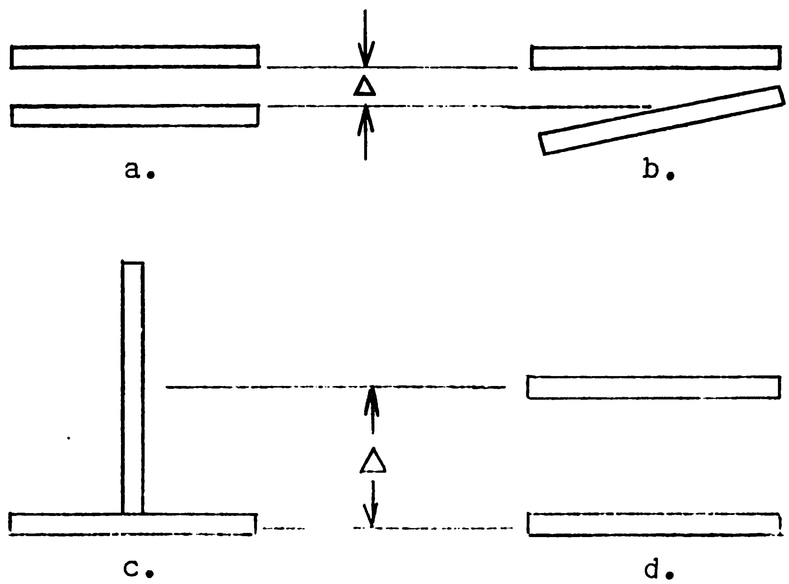


FIGURE 2 INTERPARTICLE FORCES



(after Lambe, 1958)

FIGURE 3 CHANGES IN PARTICLE ORIENTATIONS

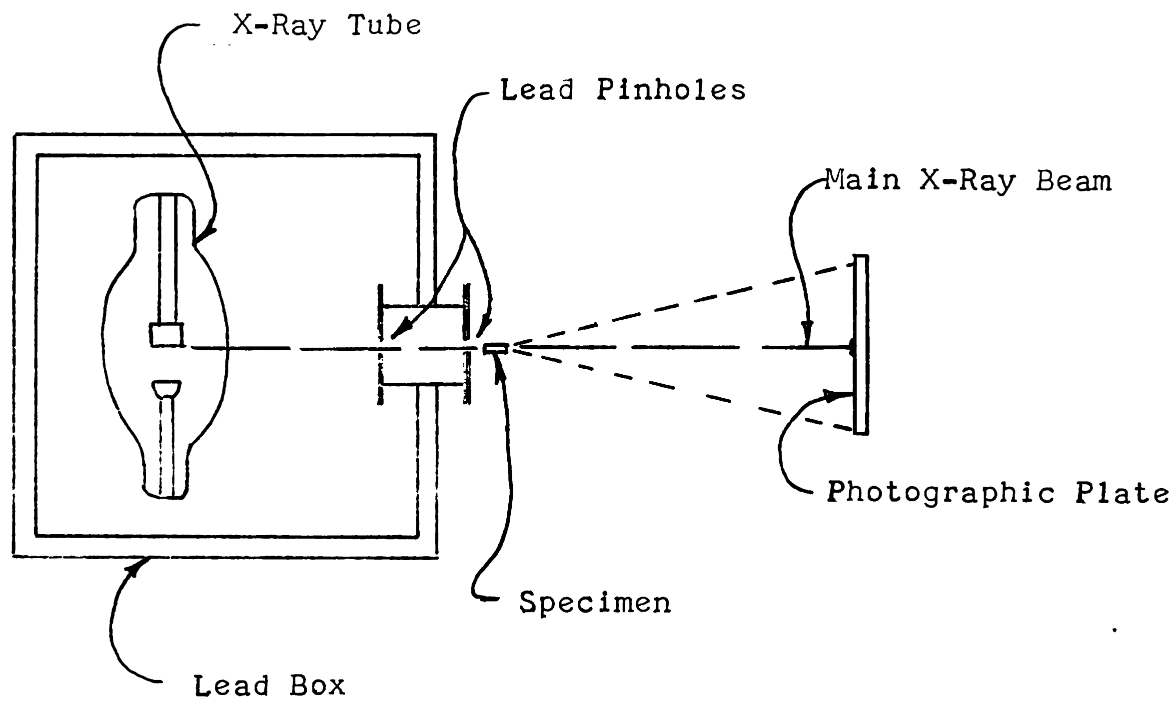
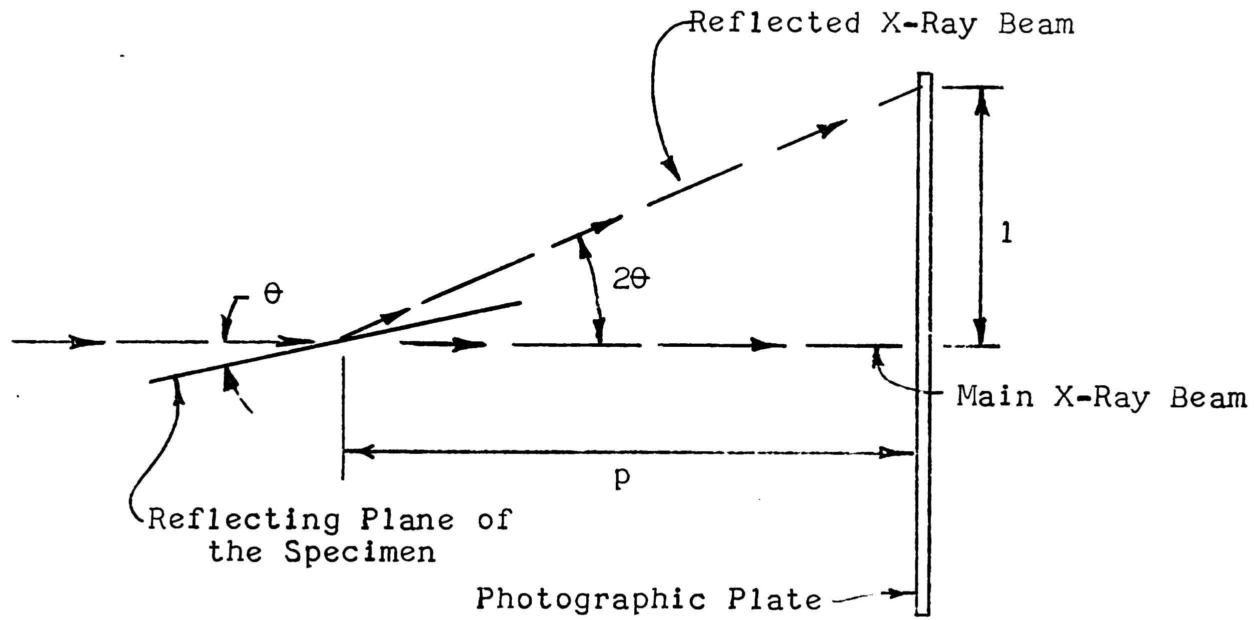
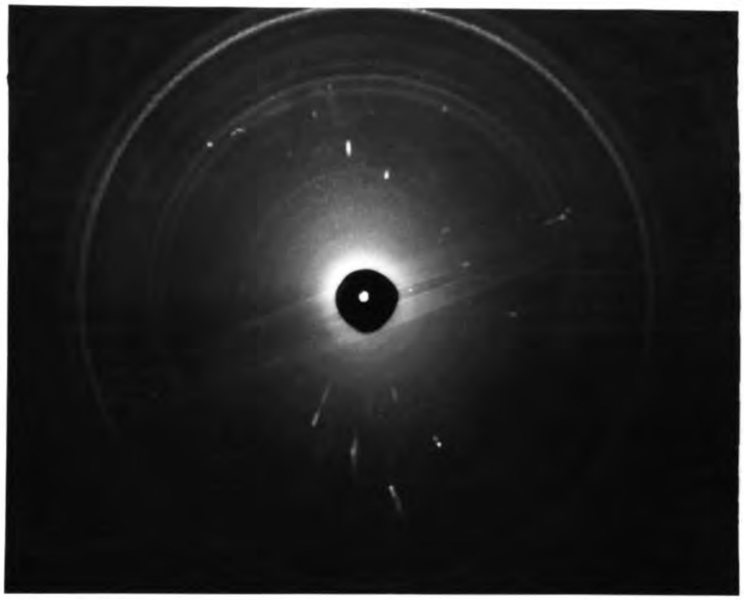


FIGURE 4 FLAT PLATE X-RAY CAMERA

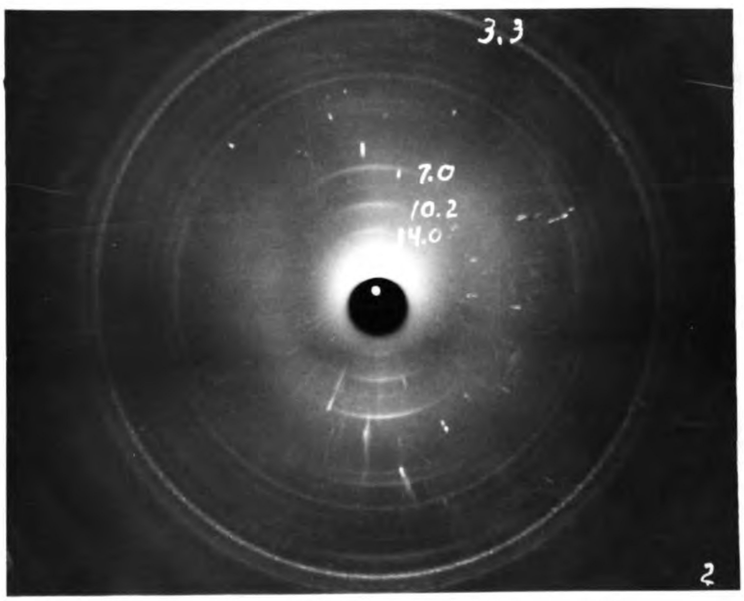


$$\tan 2\theta = \frac{l}{p}$$

FIGURE 5 ARRANGEMENT OF THE REFLECTING CRYSTAL

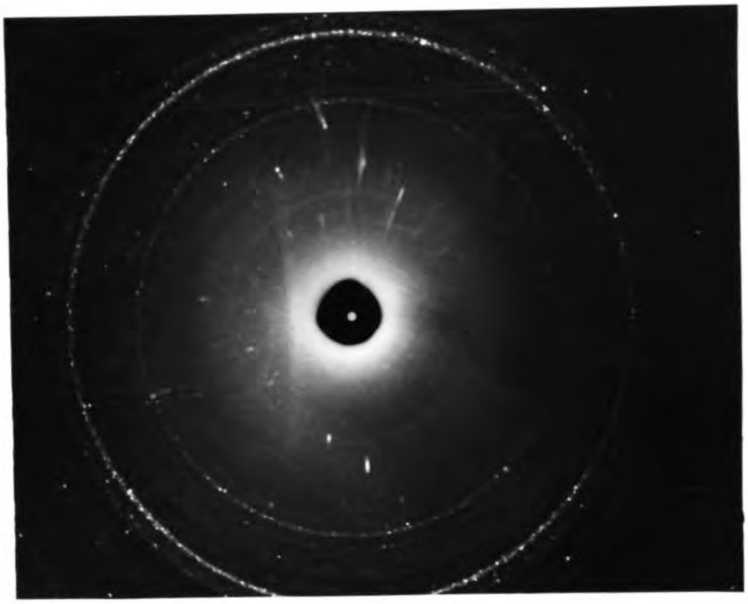


a. Powder Pattern

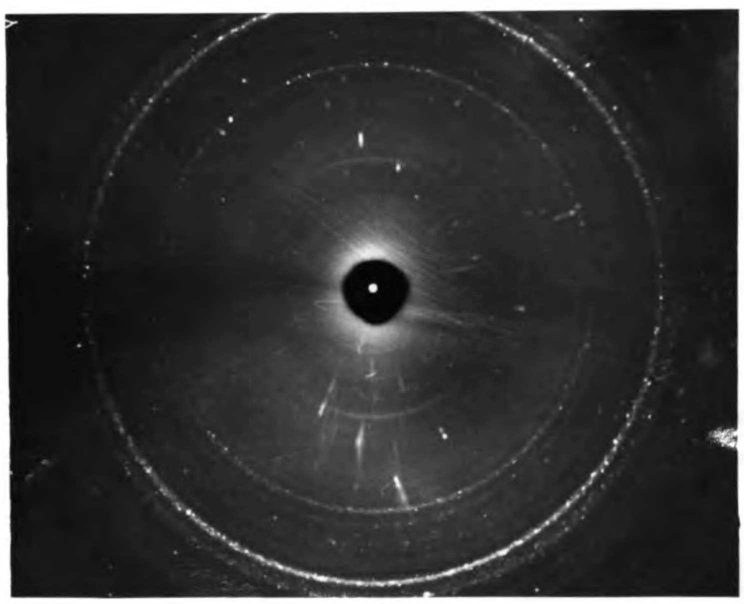


b. Oriented Film

FIGURE 6 X-RAY DIFFRACTION PATTERNS



c. Flocculated (no orientation)



d. Flocculated (some orientation)

FIGURE 6 (CONTINUED)

e. Consolidated (40 kg/cm^2)

FIGURE 6 (CONTINUED)

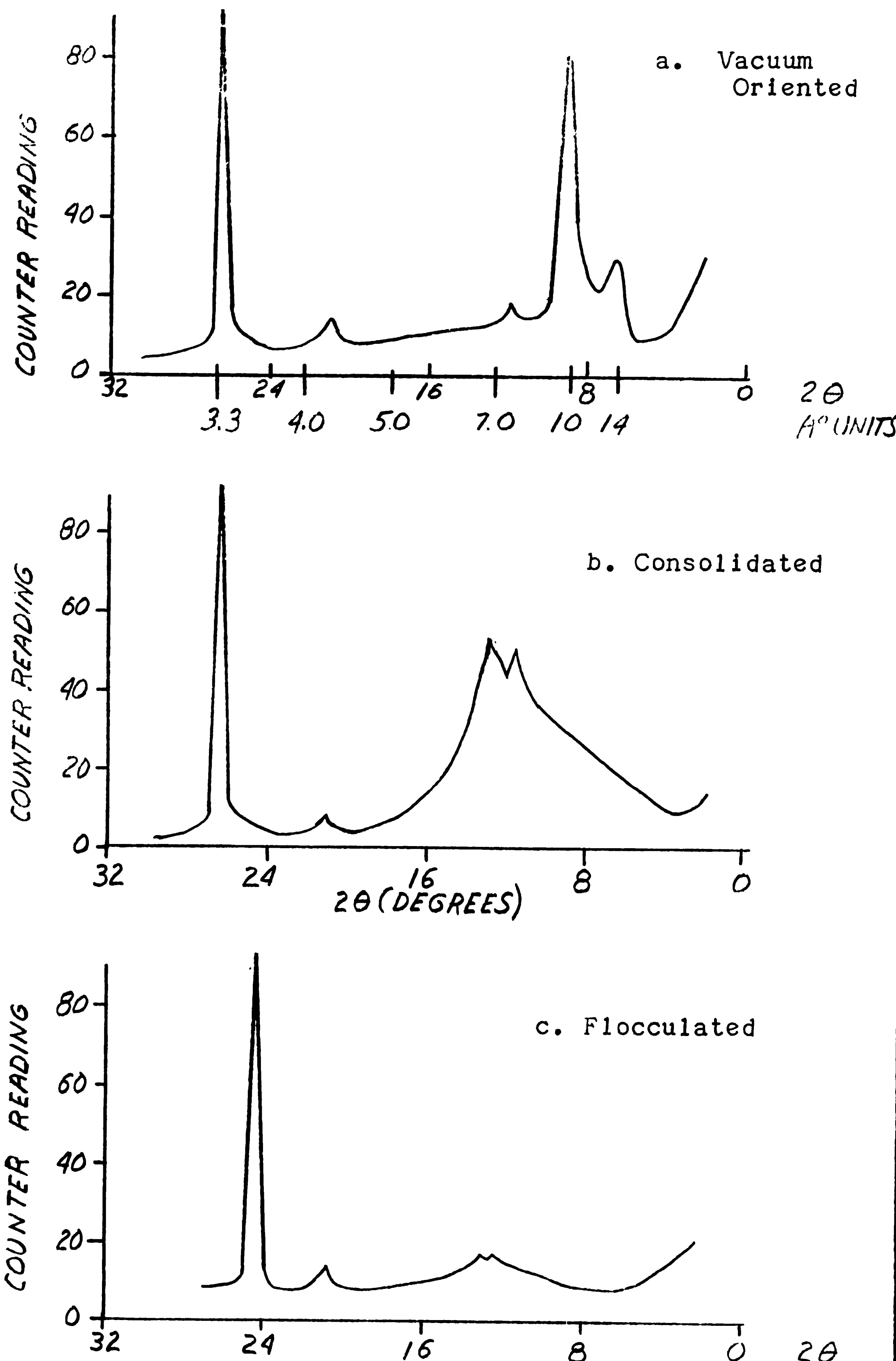


FIGURE 7 GONIOMETER PATTERNS

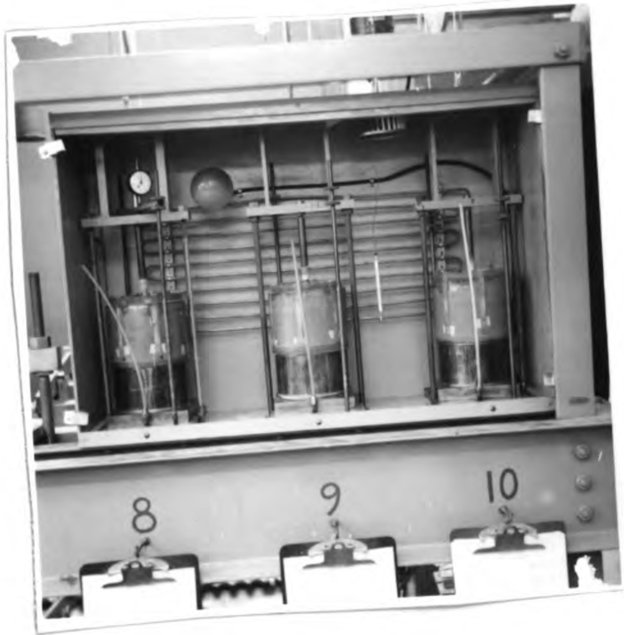


FIGURE 8 CONSOLIDOMETERS AND CONSTANT TEMPERATURE BOX

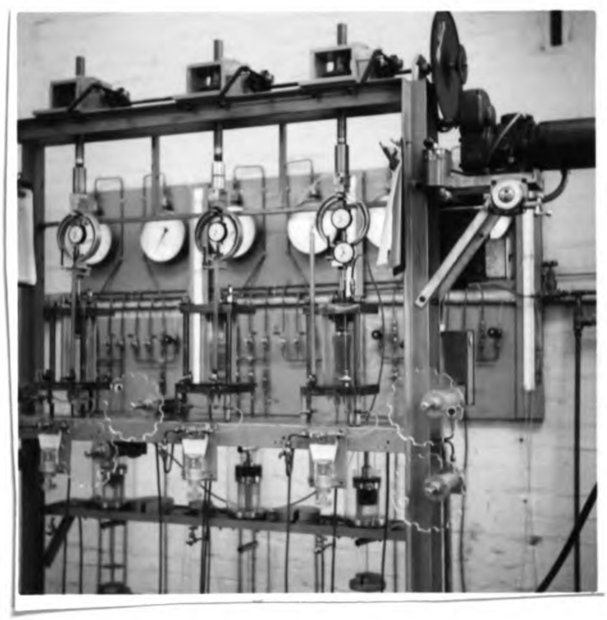
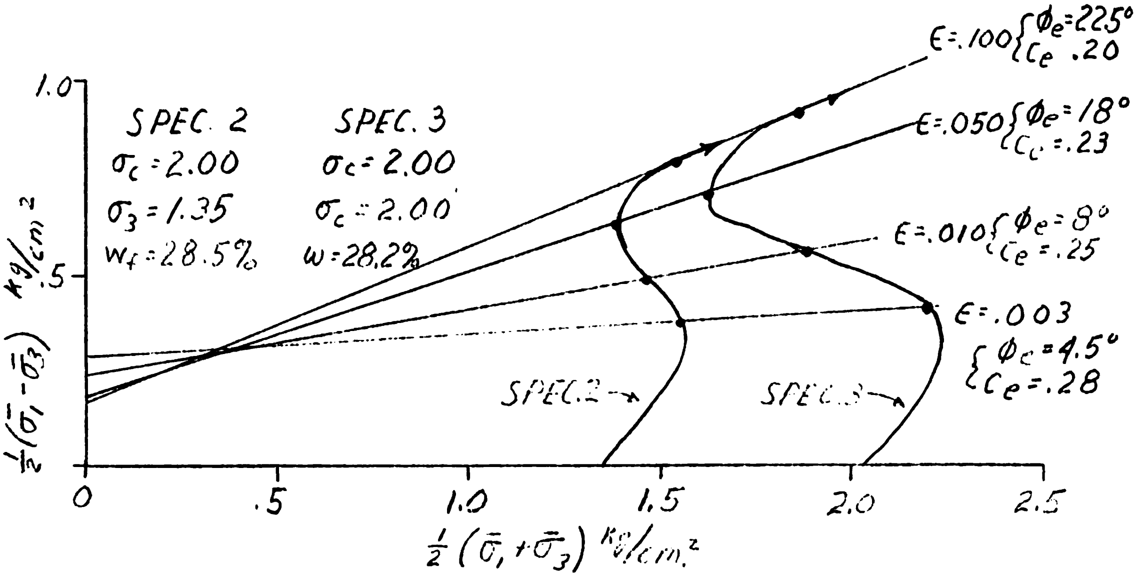
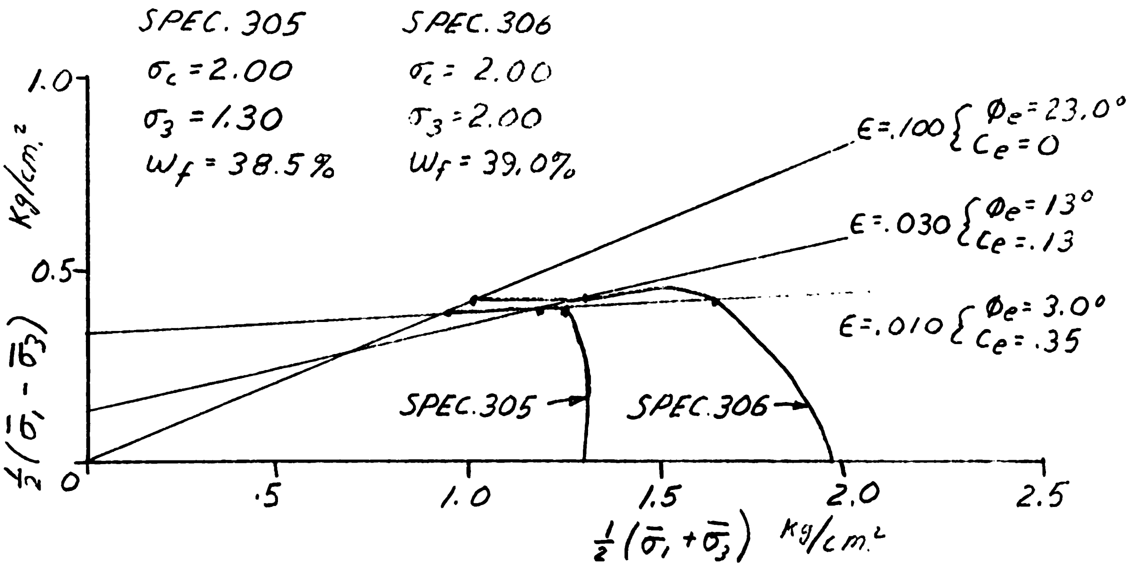


FIGURE 9 TRIAXIAL CELLS



a. Remolded Clay



b. Flocculated Clay

FIGURE 10

SHEAR AND NORMAL STRESSES, CONSTANT STRAIN RATE

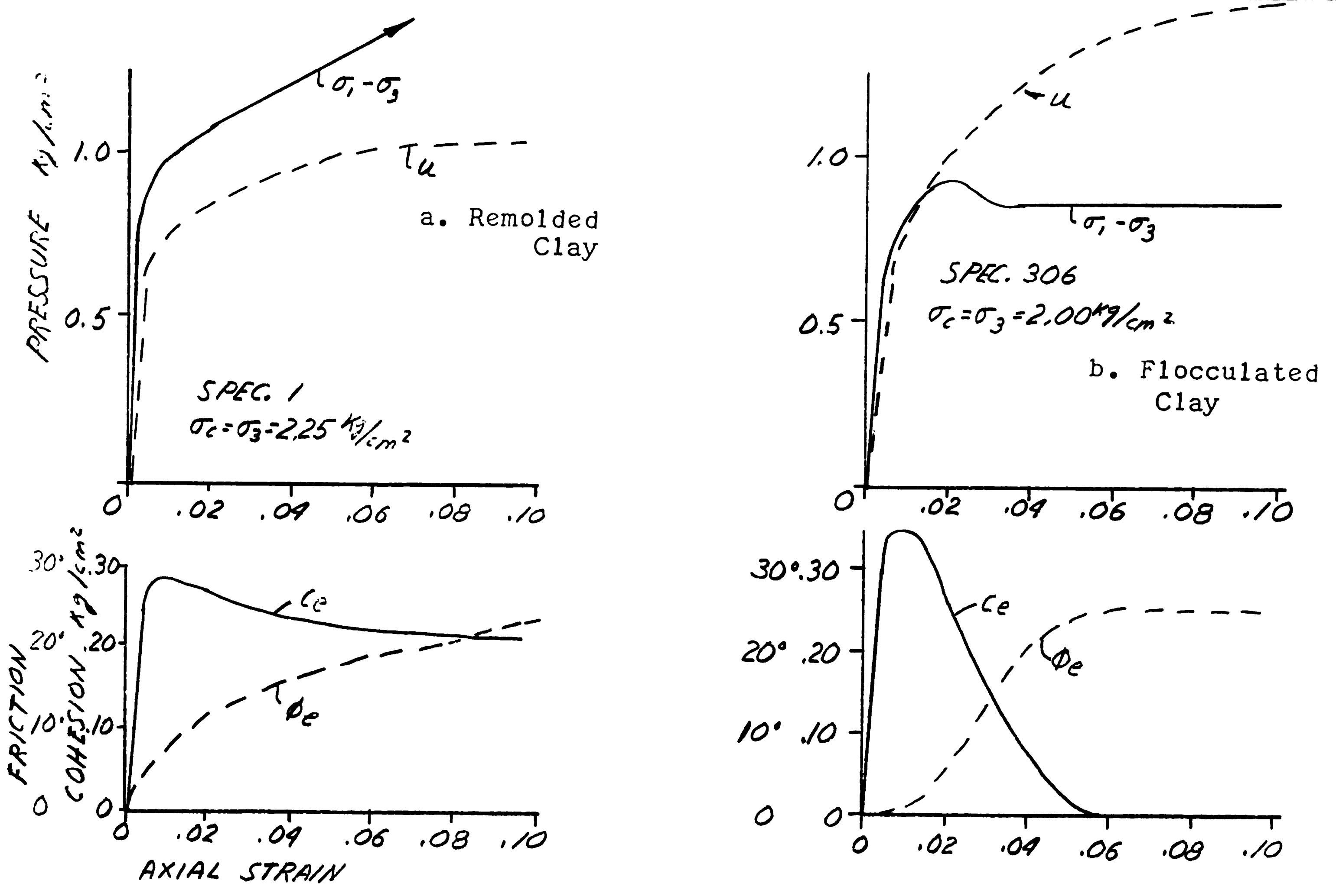
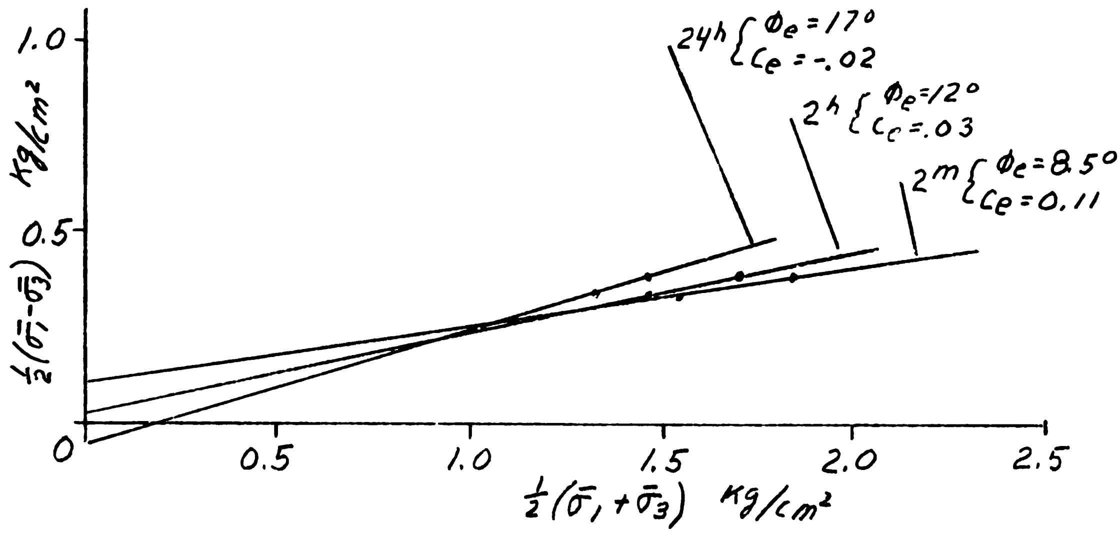
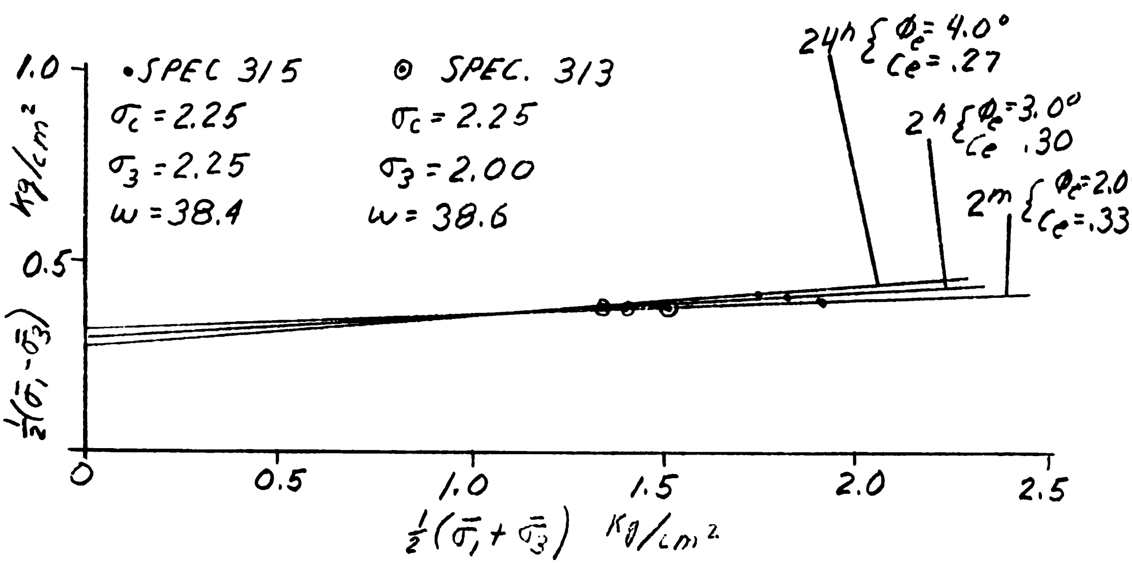


FIGURE 11 STRESS-STRAIN RELATIONSHIPS, CONSTANT STRAIN RATE



a. Remolded Clay



b. Flocculated Clay

FIGURE 12 FRICTION AND COHESION, CREEP TEST

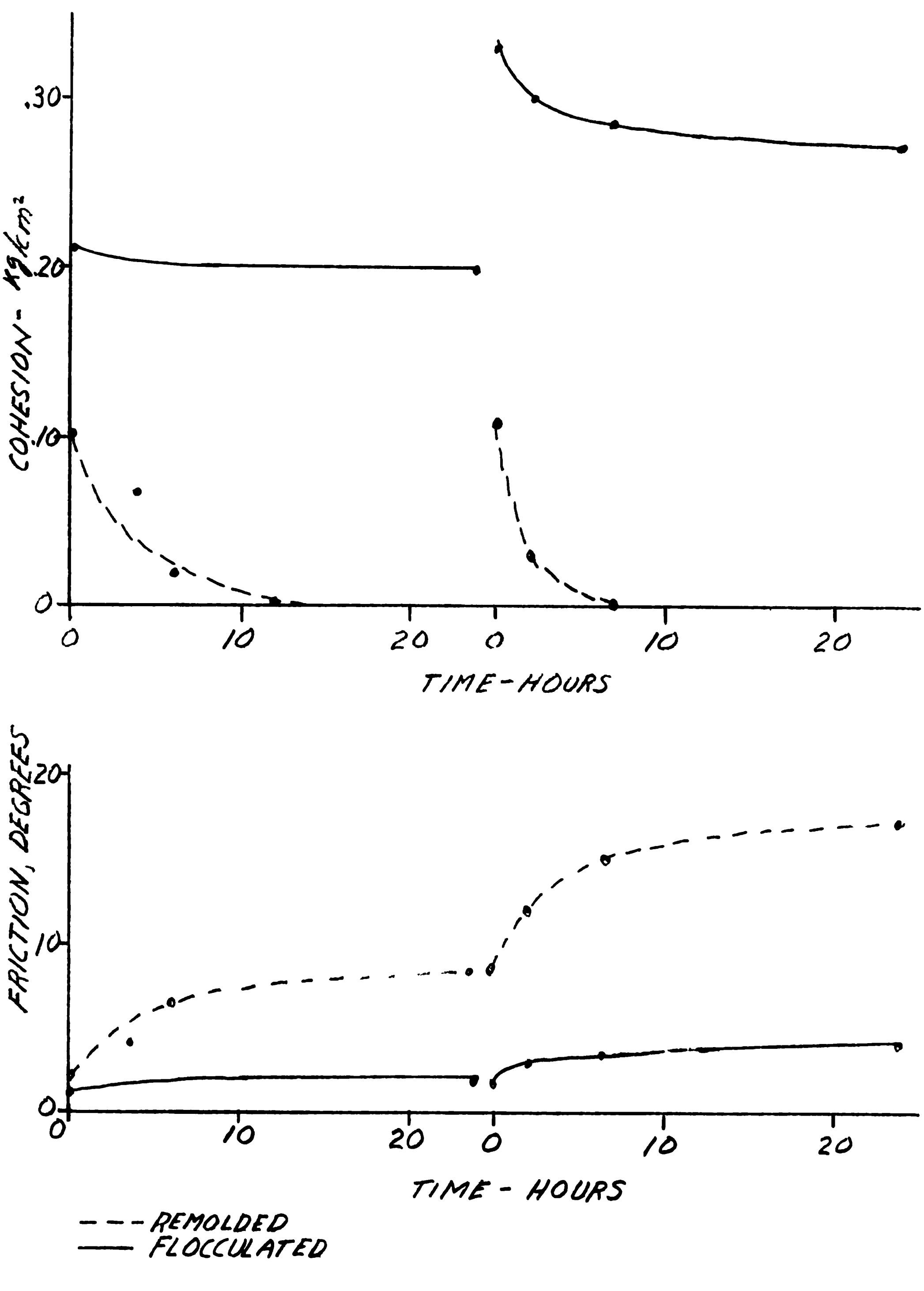


FIGURE 13 FRICTION-COHESION TIME RELATIONSHIP

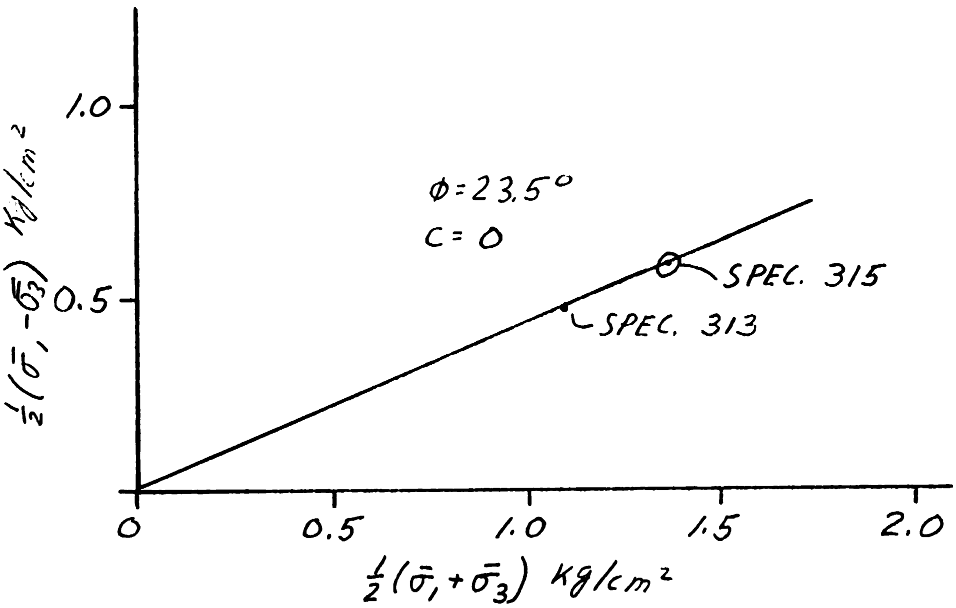


FIGURE 14 FRICTION AND COHESION AT FAILURE, CREEP TEST

TABLE 1 SOIL COMPOSITION AND CHARACTERISTICS

Composition	
Clay Fraction*	60%
Silt	40%
Sensitivity	8
Liquid Limit	55%
Plastic Limit	23%
Cation Exchange Capacity (Milliequivalents/100 grams	14
Specific Surface (Square meters/gram)	100
Total Potassium Content	2.07%

*Approximately equal percentages of illite, vermiculite and chlorite.

TABLE II SUMMARY OF TRIAXIAL TESTS

Spec. No.	Initial w	Final w	σ_c	σ_3	D_f	u_f	Type of Test
304	59.6%	38.5%	2.00	1.75	0.90	3.23	Const. Rate of Strain
305	59.5%	38.5%	2.00	1.30	0.84	3.00	
306	58.5%	39.0%	2.00	2.00	1.35	3.50	
307	59.3%	38.1%	2.50	2.00	1.35	2.10	Creep
309	60.0%	35.3%	2.25	1.75	1.05	1.56	
310	59.6%	30.1%	7.00	6.00	2.87	4.85	Const. Rate of Strain
311	60.8%	30.3%	7.00	6.50	3.05	5.50	
312	58.2%	30.4%	7.00	7.00	2.95	6.15	
313	59.4%	38.3%	2.25	2.00	0.90	2.20	Creep
314	58.7%	38.4%	2.25	1.75	0.85	2.20	
315	59.8%	38.4%	2.25	2.25	1.15	2.50	

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