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Sutherland, H.

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July 1948

UNCONFINED COMPRESSION TESTS ON

VARVED CLAYS

AT STEEP ROCK LAKE, ONTARIO

by

Hugh B. Sutherland

Soil Mechanics Section
Division of Building Research
National Research Council
Ottawa

31 July, 1948

CONTENTS

SUMMARY

In the previous work that had been carried out on Steep Rock varved clays, it had not been found possible to prepare samples for unconfined compression tests though many tests had been made in the direct action shear box apparatus and values for the angle of internal friction of the material determined (1). The present report describes a method of preparing and testing undisturbed unconfined compression test specimens from block samples. Tests showed that the specimens failed on clearly defined shear planes which intersected the bedding planes of the varves. Observations in the field of the heights at which failure took place in vertical faces cut in the clay indicated that a shear strength value of one half the unconfined compressive strength of the varved clay was a reasonable one for use in stability design calculations.

METHOD OF SAMPLING

As explained in reference (1) difficulty was experienced in obtaining suitable samples for the unconfined compression test. The varved clay has a high natural water content and a correspondingly high sensitivity ratio. Any undue disturbance of the material reduces it to a soft sticky mass which can flow easily as the natural water content lies close to the liquid limit. Sampling by ordinary sampling tube at depth produces an extremely disturbed sample with the varves almost indistinguishable, a sample which is of little use for any type of testing.

Block samples can be easily obtained, however, close to the monitoring operations and from these suitable specimens can be prepared for any type of tests. These samples are obtained as shown and described in Figure 1. The location of all the samples taken is shown in Figure 2.

PREPARATION OF TEST SPECIMENS FROM SAMPLES

Attempts to prepare unconfined compression test specimens had previously been made by forcing a sampling tube into a block sample. While specimens may be obtained in this manner, considerable distortion of the varves usually results and a drop in strength is also experienced due to the disturbance to the structure of the clay. On previous occasions, where such sampling procedure has been used in sensitive clays, the strength values obtained by test were much lower than those at which a failure actually occurred in the field. (2).

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(1) "Some Notes on Canadian Silts" by R. F. Legget and F. L. Peckover, Second International Conference on Soil Mechanics and Foundation Engineering, 1948.
(2) "Liner Plate Tunnels in the Chicago (Ill) Subway" by K. Terzaghi. Discussion by G. P. Tschebotarioff, Trans. Am. Soc. of Civil Engineers, 1943.

A vertical lathe trimming device was constructed and used in conjunction with a wire saw and mitre box to give specimens which had a minimum of disturbance and distortion and which were suitable for unconfined compression tests. With this apparatus a block sample can be trimmed down to any shape and dimensions by mounting it on a rotating base and running a fine wire saw down the face of the sample after each rotation. Details of the trimming device and the method of operation are given in the Appendix at the end of this report. Drawings of the device and mitre box are on Figures 3, 4 and 5. Each of these pieces of apparatus is made of lucite plate 3/8 of an inch thick. Lucite is an ideal material for such purposes, as it is inert, does not corrode as does steel, and can be easily cemented to form different thicknesses using a cement made by dissolving lucite in acetic acid.

APPARATUS AND TEST PROCEDURE

A loading apparatus embodying a pulley arrangement was developed to determine the unconfined compression strength of the specimens. This proved unsatisfactory and impractical due to pulley friction and was scrapped. A drawing of this apparatus is shown in Figure 6.

The trimming device described above was modified and fitted with a loading platform and a scale of tenths of an inch was marked on the loading piston. This loading apparatus was found very satisfactory in determining the unconfined compressive strength of the clay. The load required to fail the specimen was usually not more than twenty pounds, an amount which could be comfortably carried on the loading platform when a specimen approximately 1.4 inches diameter was used. If the clay was stronger, smaller square prism specimens were prepared so that no total failing load greater than twenty pounds need be used. The loads were applied in approximately equal increments at equal time intervals and the apparatus could be described as the constant stress type of apparatus. Details of test procedure method of calculation and method of recording the data are given in the Appendix. No remoulded samples were tested as the natural water contents were close to the liquid limit. In such a case the theoretical remoulded strength should be zero.

SIZE AND SHAPE OF SPECIMENS

As stated above, specimens of different sizes and shapes were used. The most common type of specimen was a cylinder 1.4 inches diameter and 3 inches high. Tests were also conducted on square prisms of 1.4 inch side and 3 inches high and approximately 0.75 inches side and 1.7 inches high. No appreciable differences were found in the strength values obtained using these different shapes of specimens.

NATURE AND DIRECTION OF LOAD APPLICATION

As a preliminary to the main testing, specimens cut from the same block sample were tested:

(a) with the loading applied at right angles to the direction of the bedding of the varves;

(b) with the loading applied parallel to the direction of the bedding of the varves.

The values for compressive strength obtained by each method agreed closely within the limits of experimental error. All subsequent tests were made with the loading applied at right angles to the direction of the bedding of the varves.

RESULTS

A complete summary of all the test results is given in Figure 7 at the end of this report.

Form of Failure

Failure of the specimens occurred rapidly and with little warning. In practically all specimens tested, failure took place at a low value of strain. The average value of strain at failure was 4.4%, which indicates a brittle type of failure. In only one case did a plastic failure occur, at a strain of 18.9%. This took place in a clay with sandy layers.

The majority of specimens tested showed very definite shearing surfaces which intersected the plane of the bedding of the varves. The average inclination of the shear failure surfaces to the horizontal was approximately 58°. This type of failure is that which is usually encountered when testing homogeneous clays. In no case did failure occur due to spreading of one layer of the varves in the clay, neither did failure occur along one layer of a varve.

Strength-Water Content Relationships

Visual inspection of the block samples is sufficient to show that the material in the summer layer of the varve is different from the material in the winter layer. This difference is reflected in the considerable differences encountered in natural water content of these materials. In some of the samples taken, the summer layers were composed of layers of fine sand. The natural water contents of the block samples vary considerably from block to block depending on the proportion of coarser material in the block, though there are little differences of natural water content within each block (except from one layer to another of the varves).

Natural water contents of each specimen were taken after each test and a plot made of natural water content at failure versus unconfined compression strength. This is as shown in Figure 8. It is evident that no correlation can be obtained between natural water content and unconfined compressive strength, where material from different block samples is considered. However, within any one block there is a tendency towards increased unconfined compressive strength with decreased natural water content.

Attempts at obtaining water content relationships in varved clays are difficult, due to the variation in natural water content from layer to layer of the varve. When water contents are taken one can never be sure as to what proportion of each layer of the varve is contained in the specimen being investigated. Specimens taken from the same block sometimes show large differences in natural water content due to this reason.

Modulus of Deformation

An attempt was made to determine a value of the modulus of deformation for each specimen tested, the modulus being defined arbitrarily as the slope of the line joining the stress at half the failure strain to the origin of the stress strain curve. This attempt was not successful and no consistency was obtained in the results. This is due to the difficulty of accurately measuring the small values of strain which occurred under each load increment. Deformation of the specimen could only be measured by estimation to one hundredth of an inch.

The Significance of the Unconfined Compression Test in Varved Clays

A simplified method of analysing stability problems in cohesive soils in Great Britain is that known as the $\phi = 0$ method. Shear strength values are taken as one half the deviator stress values in the quick triaxial tests or one half the axial pressure under which a specimen fails in the unconfined compression test. Dr. Terzaghi has stated (2) -- "he has found repeatedly (in striking contrast to what one should expect from the test results) that slopes in soft, undisturbed clays fail if the average shearing stress on the potential surface of sliding becomes roughly equal to one half the average nonconfined compressive strength of fairly undisturbed samples, regardless of the depth of the overburden--". Dr. Terzaghi had reserved an opinion as to the applicability of this stress relationship to varved clays (2). It has been shown from the tests described in this report that the form of failure in varved clays agrees with the form of failure in homogeneous clays in so far as the angle of the shear failure surface is similarly inclined to the major and minor principal planes of the test specimens. A similar type of failure of course takes place in cohesionless soils where the soil type does not allow the theoretical relationship of shear strength being equal to one half the unconfined compressive strength to develop.

(2) "Liner Plate Tunnels on the Chicago, Ill. Subway" by Karl Terzaghi. Trans. Am. Soc. C. E. 1943. p.907-1008 and 1090-1097.

However, the fact that failure in varved clays does not take place along the varves as has been suggested, but takes place in accordance with the general laws of the mechanics of failure indicates that the unconfined compressive strength test can be accepted as equally suitable for homogeneous clays and varved clays and that the shear strength may be taken as equal to one half the unconfined compressive strength.

Further evidence lies in the height to which an unsupported vertical face can be cut in the varved clay. Terzaghi shows (2) that the maximum height in feet to which a vertical cut can be made in clay is $3.85 \frac{c}{w}$ where c = the cohesion of the clay lb/ft^2

w = density of the clay in place lb/ft^3

In an area at Steep Rock where an average value of shear strength of 575 lb/ft^2 (equal to one half the average unconfined compression strength) and a density value of 103 lb/ft^3 was measured, the theoretical maximum height of vertical face was 22 feet. Observations showed that vertical faces in the clay did not stand unsupported above a height of approximately 20 to 25 feet. Exact measurement of the height of these unsupported vertical faces was not possible. Thus where a value for shear strength equal to one half the unconfined compressive strength was taken, reasonable agreement was obtained between the theoretical and actual heights of unsupported vertical faces in the clay. This indicates that the assumption for the shear strength value is a reasonable one.

Application of Unconfined Compression Strength Values in Practice

The major use to which a knowledge of shear strength of the varved clay at Steep Rock Lake can be put is in the design of the stability of the slopes to be cut in the clay. This problem has been dealt with in detail in a memorandum submitted to the Steep Rock management wherein suggestions are made for safe cutting of the slopes on the basis of the shear strength tests described in these notes.

A knowledge of shear strength of cohesive soils is very helpful when determining the bearing capacity of such soils when they underlie foundations. The ultimate bearing capacity of such soils is approximately six times the shear strength. Using a factor of safety of 3, the bearing capacity of a cohesive soil can be taken as equal to the unconfined compressive strength. This gives protection against failure of the soil by rupture, but investigations should be conducted to ensure that no undue settlements are likely to occur (3).

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(2) "Soil Mechanics in Engineering Practice" by Terzaghi and Peck. Page 186. John Wiley and Sons, 1948.

(3) "Soil Mechanics in Engineering Practice" by Terzaghi and Peck. pp.420-434. John Wiley and Sons, 1948.

CONCLUSIONS

1. By the use of a vertical lathe trimming device, samples which are practically undisturbed can be cut and prepared for the unconfined compression test.

2. The size and shape of the specimens tests in the unconfined compression apparatus does not affect the unconfined compressive strength of the specimen.

3. Evidence was submitted whereby the shear strength of the varved clay at Steep Rock Lake could be taken as one half its unconfined compressive strength.

4. No relationship was found to exist between the natural water content and the unconfined compressive strength of the samples tested, these samples being taken from representative points across the site.

5. No consistent values could be obtained for an arbitrarily defined modulus of deformation of the clay.

6. Knowing the shear strength of the varved clay, design calculations can be made for the stability of slopes cut in the clay, and also the bearing capacity of the varved clay can be obtained.

APPENDIX

Procedure for Determining the Unconfined Compression Strength of a Cohesive Soil

Apparatus

Combined Trimming and Testing Device
Weights
Wire Saw
Balance for Determining Water Contents
Tins or Dishes for Water Content Determination
Mitre Box
Measuring Scale

Procedure

1. Obtain an undisturbed block sample from the site, as described in Figure 1 of the report, wrapping it in waxed paper as soon as it is taken to prevent loss of water content. Mark the sample adequately so that its location is known, i.e., specify co-ordinates and altitude of spot from where specimen was taken.

2. By means of a wire saw, cut from the sample a specimen of such dimensions (approximately 3½ inches long by 1 3/4 inches square) so that it can just fit into the sample trimmer sketched in Figure 1. This sample trimmer has two vertical faces eccentric on its centre line. Cutting along these faces gives specimens either 1.4 inches diameter or 1.5 inches diameter. Rough cutting can be on the 1.5 inch diameter face and the specimen trimmed down to 1.4 inches diameter by use of the other face. As the specimen is rotated on the lower base plate the wire saw is run down the vertical faces. Only the bottom plate should be used to rotate the specimen, which is retained in position by pins set into the base. This operation should be carried out as quickly as possible to prevent loss of moisture. If the specimen is strong, smaller square prisms may be cut for testing. This can be done by using the markings set out on the lucit base piece.

3. Transfer the specimen to the mitre box. The specimen is laid in the box and trimmed by the wire saw running against the sides of the vertical pieces. Care should be taken to ensure clean cuts and that the base and top of the specimen are at right angles to its vertical axis.

4. Carefully measure the dimensions of the trimmed specimen and weigh it. Enter these dimensions in the data sheet. The volume of the specimen can be computed from these measurements. The specimen may be covered with a coating of light oil to prevent drying out during testing.

5. Re-centre the specimen on the base of the apparatus, lining it up under the piston in two directions at right angles. The piston and the vertical axis of the specimen must lie in the same vertical line.

6. The initial load on the specimen is the weight of the piston and loading platform. This equals 0.55 lb. Read the initial deformation value from the scale on the piston. The graduations are in tenths of an inch and readings can be estimated to hundredths of an inch.

7. Apply loads to the platform at intervals of 30 seconds, reading the deformation of the specimen at 15 seconds after each load application. Continue this till the specimen fails. The initial load should be 2 lb. and load increments of 1½ lb. can be used, decreasing these increments to smaller values when signs of failure become apparent.

8. If shear planes have developed, sketch them showing their inclination to the horizontal.

9. Determine the water content of the specimen after failure.

10. Calculate the failure stress and the failure strain. The method of calculation is as shown below.

The density of the material can also be computed knowing the volume and the weight of the cylindrical specimen.

<u>Precautions</u>

1. Oil piston and bushing before test to cut down friction losses.

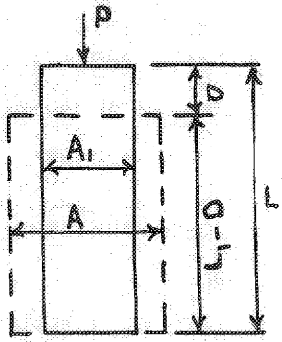
2. Make sure there is no binding action between the piston and bushings. This can be ensured by placing the apparatus on a smooth horizontal base so that the loading piston is truly vertical.

3. Do not allow the specimen to dry out. Cover with waxed paper if not testing immediately after trimming.

4. The specimen should be about twice its diameter (or side dimension) in length.

Method of Calculation

The deformation readings are taken to give an indication of the magnitude of the strain at failure. As the deformation progresses the cross-sectional area of the specimen increases and allowances must be made for this increase when computing the stresses. When making such an allowance the specimen is assumed to remain cylindrical in shape and of constant volume. Thus, let



original length of specimen	$= L_1$
length at failure	$= L$
original cross-sectional area	$= A_1$
cross-sectional area at failure	$= A$
deformation	$= D$
load at failure	$= P$

Then, strain $= \dfrac{D}{L_1}$ and $AL = A_1L_1$ and $L_1 - D = L$

Corrected area (i.e. cross-sectional area allowing for deformation) equals:

$$A = \frac{A_1L_1}{L} = \frac{A_1L_1}{L_1-D} = \frac{A_1}{1 - \frac{D}{L_1}} = \frac{A_1}{1\text{-strain}}$$

Therefore, stress at any load $= \dfrac{\text{Load}}{\text{Corrected area}}$

Name ______________________ Sample and Test No. ______________

Date ______________________ Sheet No. ______________

UNCONFINED COMPRESSION TEST

Description of sample: ____

____

____

Apparatus used: ____

Free height of sample at start of test = H_1 = __________ in. = __________ cm

At start of test: Area of sample Top = __________ = __________

Bottom = __________ = __________

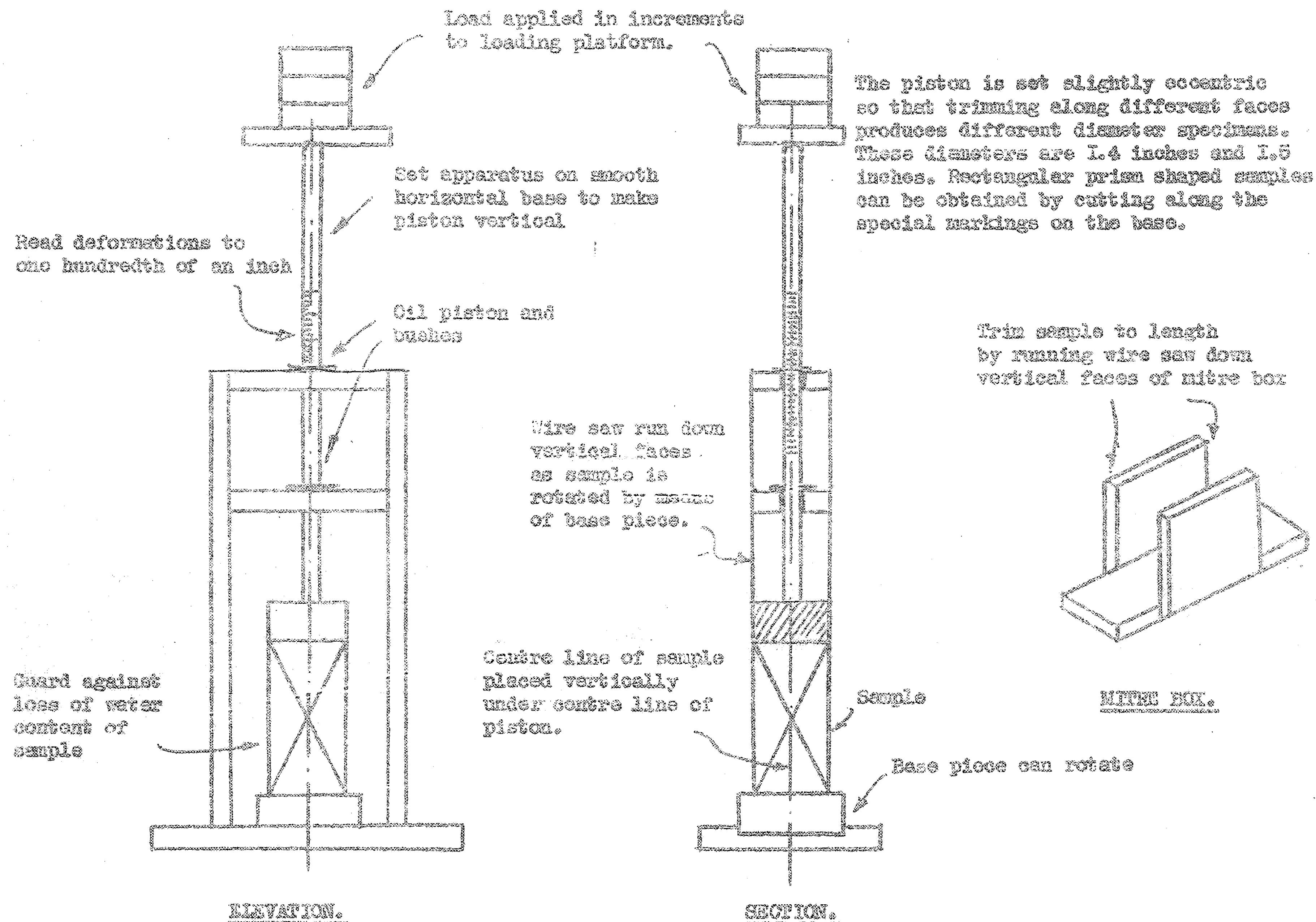
Centre = __________ = __________

Average cross-sectional area of specimen = ______________ = A_1

Rate of load application: ____

Load Increment lb.	Total Load lb.	Piston Reading ins.	Deformation ins.	Strain	Corr. Area in.^{2}	Stress lb./in^2	Water Content Determination Wt. Wet Top		Remarks
							Wt. Wet Top		
							Wt. Dry		
							Wt. Water		
							Tare		
							Wt. solid		
							W%		
							Wt.Wet Centre		
							Wt. Dry		
							Wt. Water		
							Tare		
							Wt. solid		
							W%		
							Wt. Wet Bottom		
							Wt. Dry		
							Wt. Water		
							Tare		
							Wt. solid		
							W%		

Note: Corrected Area $= \dfrac{A_1}{1 - \text{strain}}$



SAMPLE TRIMMER AND
UNCONFINED COMPRESSION TEST APPARATUS.

H. B. Sutherland
July 1948

UNCONFINED COMPRESSION TESTS

ON VARVED CLAYS AT STEEP ROCK LAKE, ONTARIO

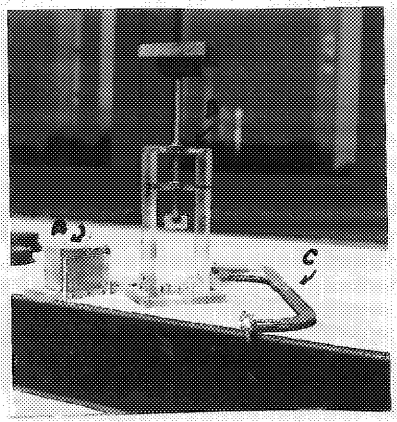
PHOTOGRAPHIC RECORD OF PREPARATION

AND TESTING OF SPECIMENS

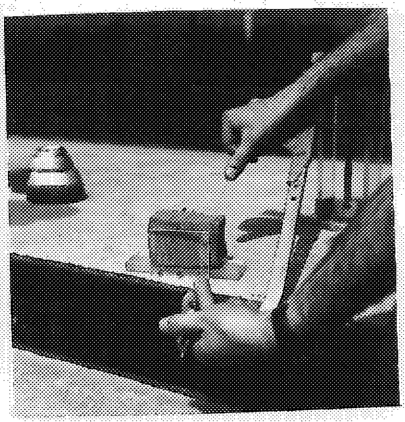
Soil Mechanics Section
Division of Building Research
National Research Council
Ottawa

18 August, 1948

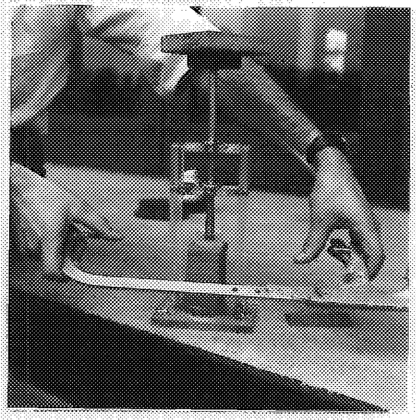
H.B.S.



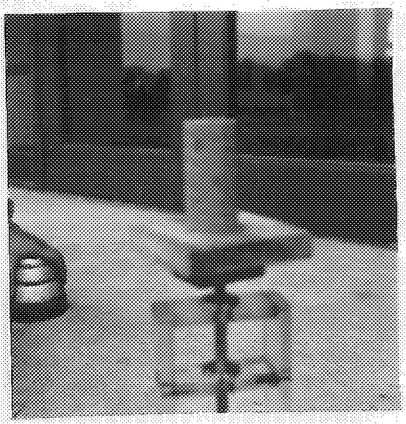
1. Apparatus Used in Testing
A. Mitre Box B. Combined Trimming and Testing Device
C. Wire Saw



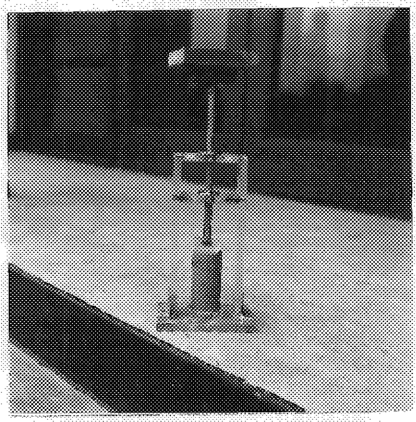
2. Specimen Being Trimmed To Length and With Parallel Ends in Mitre Box.



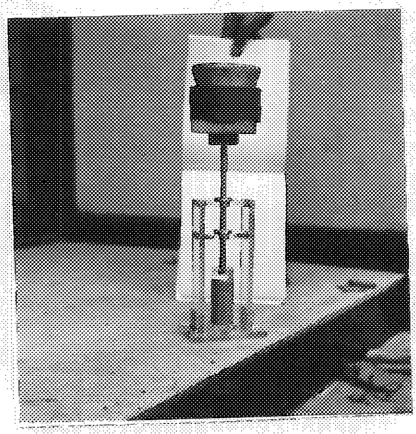
3. Cylindrical Specimen Being Prepared in the Sample Trimming Device



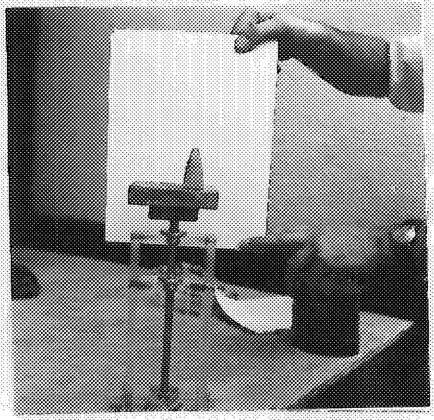
4. Cylindrical Specimen Ready to be Tested



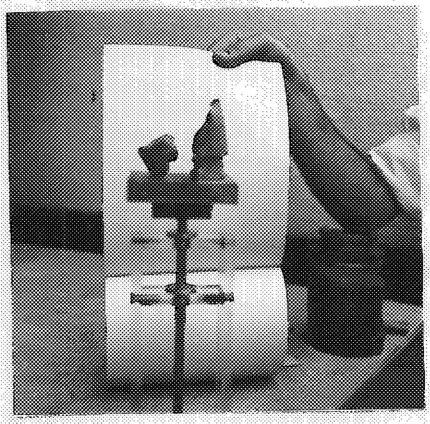
5. Cylindrical Specimen Set Up In Apparatus Ready For Testing



6. Loading Being Applied to Cylindrical Specimen



7. Specimen After Failure Showing
Shear Failure Surfaces Developed



8. Shear Failure Surface
Developed in Specimen

METHOD OF OBTAINING BLOCK SAMPLES OF VARVED CLAY AT STEEP ROCK LAKE, ONTARIO

APPARATUS: SPADE, TROWEL, WIRE SAW, WAXED PAPER

PROCEDURE:

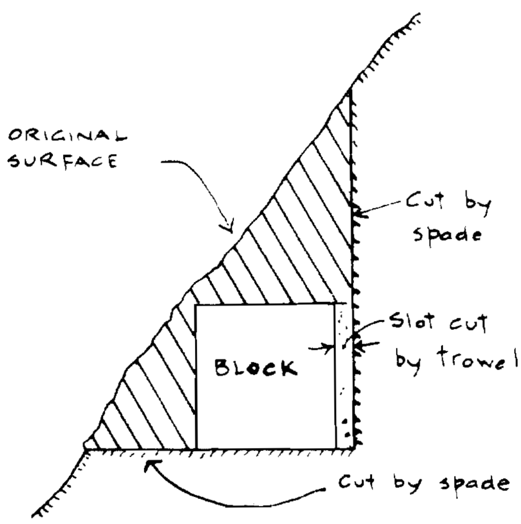
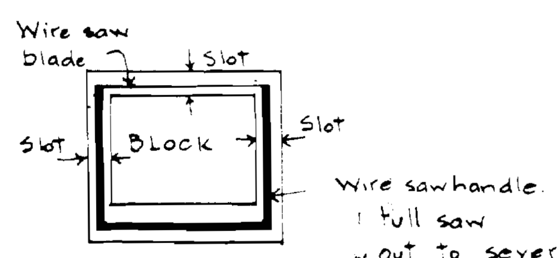


FIGURE 1



PLAN
FIGURE 2

1. Remove dried out material from the surface
2. Remove material shown hatched in Figure 1.
3. Cut slots around the block with the trowel. (Figure 2)
4. Place wire saw around the block, and pull the wire through the sample at base level. (Figure 2)
5. Remove the sample with the aid of the spade.
6. Mark top and bottom of the sample
7. Wrap sample in waxed paper
8. Remove sample to laboratory and encase in paraffin wax.
9. Store sample in a box of damp sawdust until it is to be used.
10. Obtain co-ordinates of sample location and altitude of sample

METHOD OF OBTAINING BLOCK SAMPLES OF VARVED CLAY AT STEEP ROCK LAKE, ONTARIO

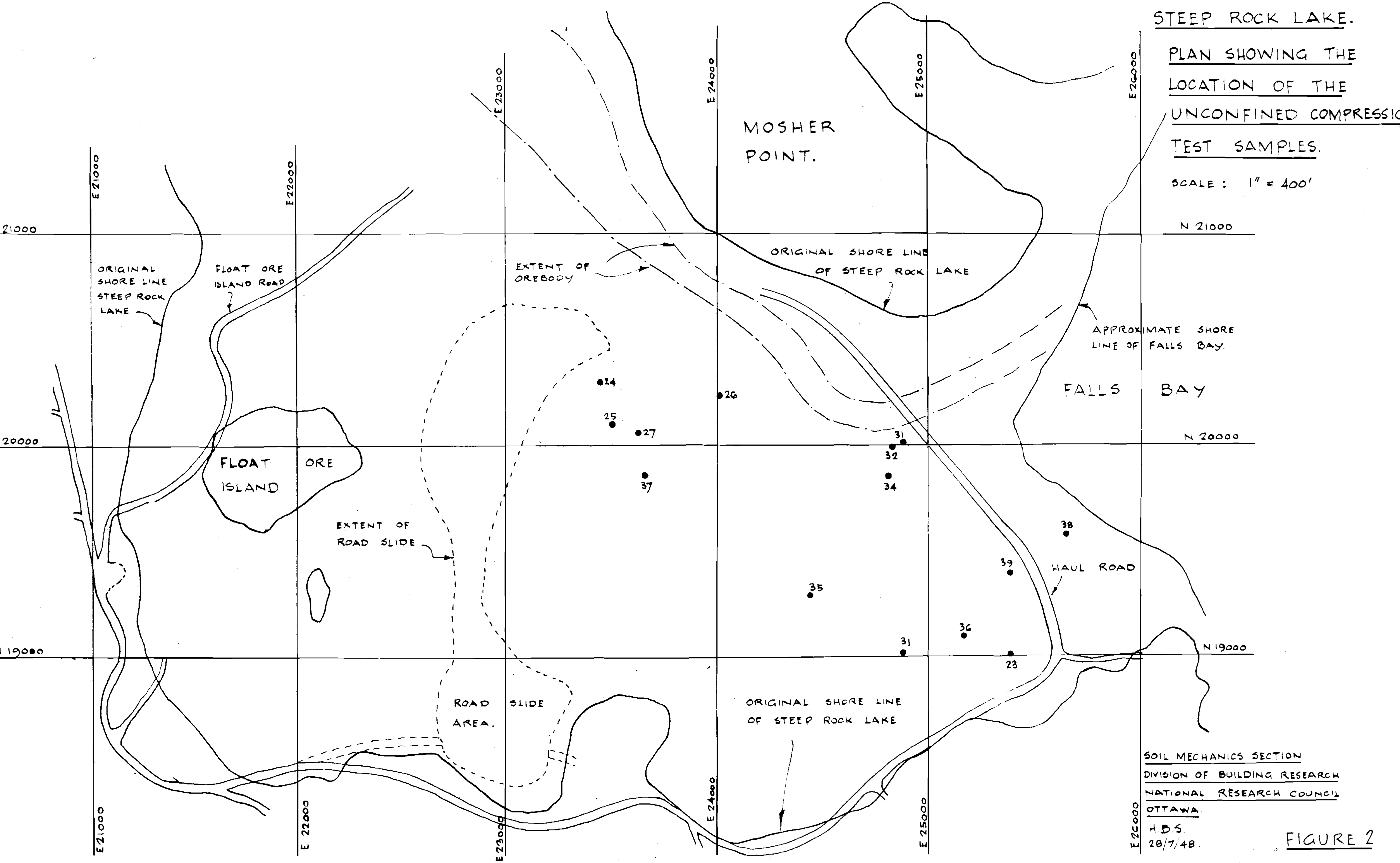
APPARATUS: SPADE, TROWEL, WIRE SAW, WAXED PAPER

PROCEDURE:

STEEP ROCK LAKE.

PLAN SHOWING THE LOCATION OF THE UNCONFINED COMPRESSION TEST SAMPLES.

SCALE : 1" = 400'



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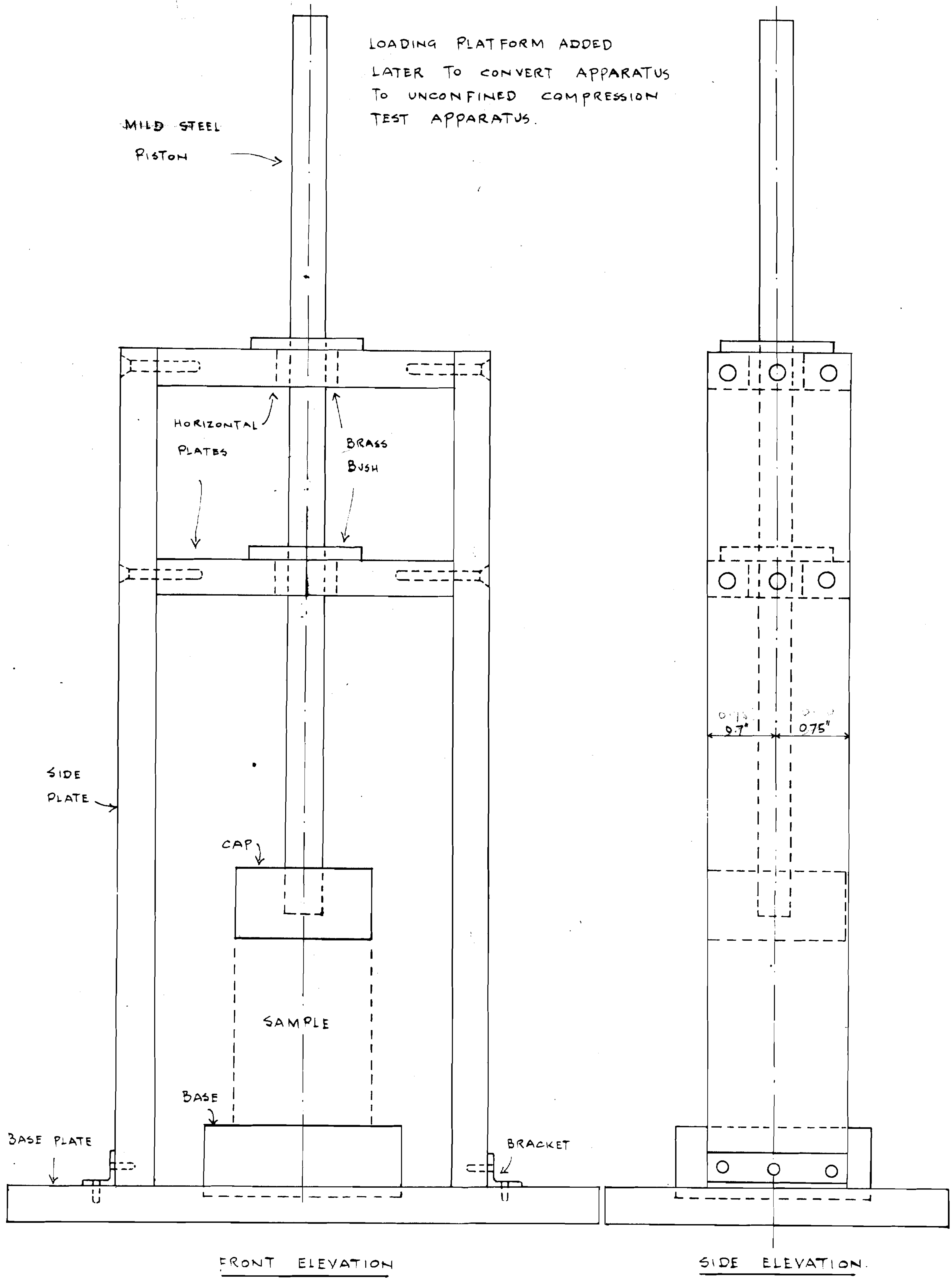
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL
OTTAWA.
H.B.S.
28/7/48.

FIGURE 2



CLAY SAMPLE TRIMMER

(SUBSEQUENTLY CONVERTED TO COMPRESSION TESTING DEVICE)

SCALE: FULL SIZE.

(FOR DETAILS OF PARTS DESCRIBED ABOVE SEE FIGURE 4.)

FIGURE 3.

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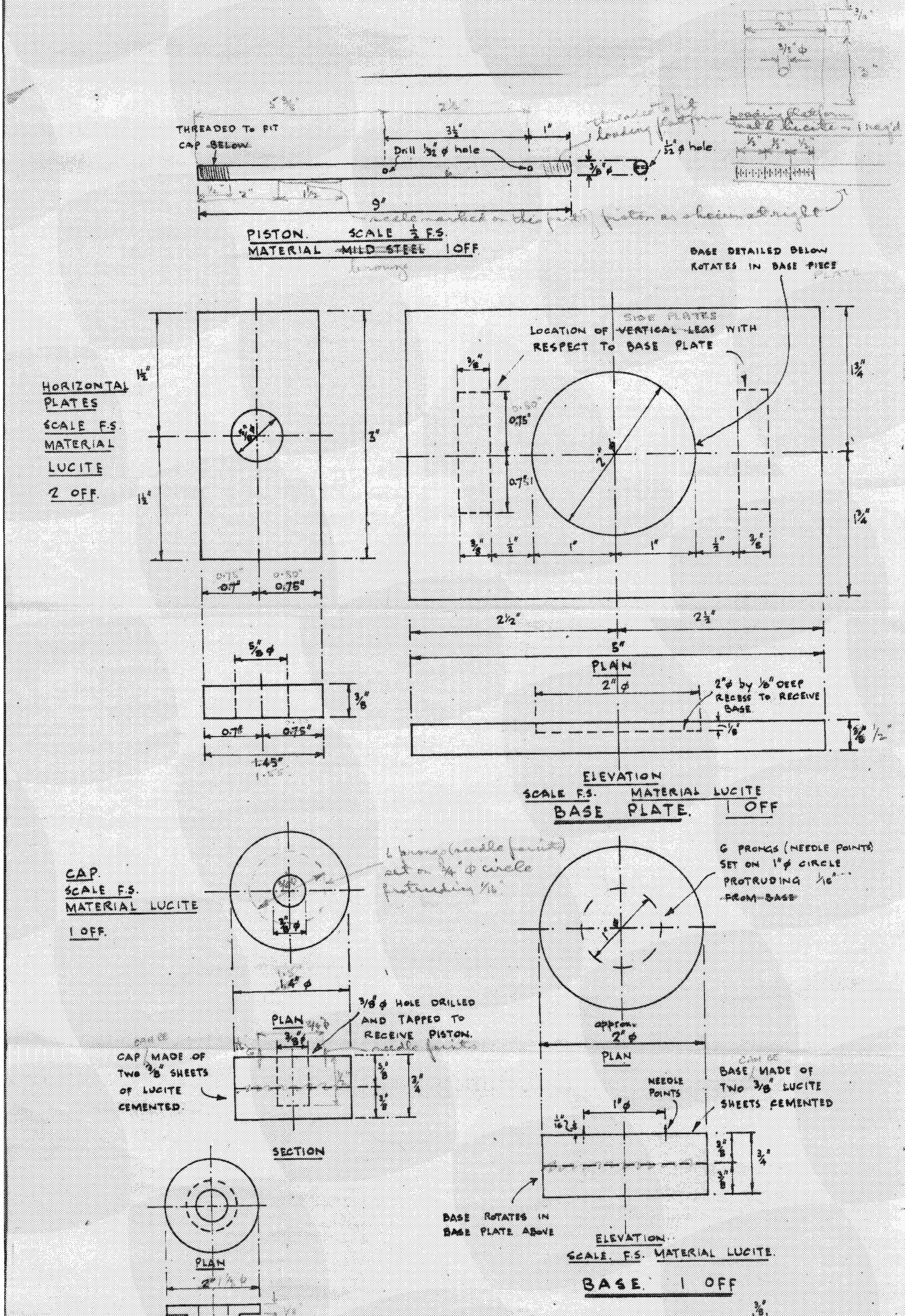

THREADED TO FIT CAP BELOW
Drill 1/32" ϕ hole
1/32" ϕ hole
3/8" ϕ
9"
PISTON. SCALE ½ F.S.
MATERIAL MILD STEEL 1 OFF
BASE DETAILED BELOW ROTATES IN BASE PIECE
HORIZONTAL PLATES
SCALE F.S.
MATERIAL
LUCITE
2 OFF.
3"
0.75"
5/8" ϕ
1.45"
LOCATION OF VERTICAL LEGS WITH RESPECT TO BASE PLATE
2"
2½"
5"
PLAN
2" ϕ
2" ϕ by 1/8" DEEP RECESS TO RECEIVE BASE.
ELEVATION
SCALE F.S. MATERIAL LUCITE
BASE PLATE. 1 OFF
CAP.
SCALE F.S.
MATERIAL LUCITE
1 OFF.
1.4" ϕ
PLAN
3/8" ϕ HOLE DRILLED AND TAPPED TO RECEIVE PISTON.
CAP MADE OF TWO 3/8" SHEETS OF LUCITE CEMENTED.
SECTION
6 PRONGS (NEEDLE POINTS) SET ON 1" ϕ CIRCLE PROTRUDING 1/16" FROM BASE
approx. 2" ϕ
PLAN
NEEDLE POINTS
1" ϕ
BASE MADE OF TWO 3/8" LUCITE SHEETS CEMENTED
BASE ROTATES IN BASE PLATE ABOVE
ELEVATION
SCALE F.S. MATERIAL LUCITE.
BASE 1 OFF
PLAN

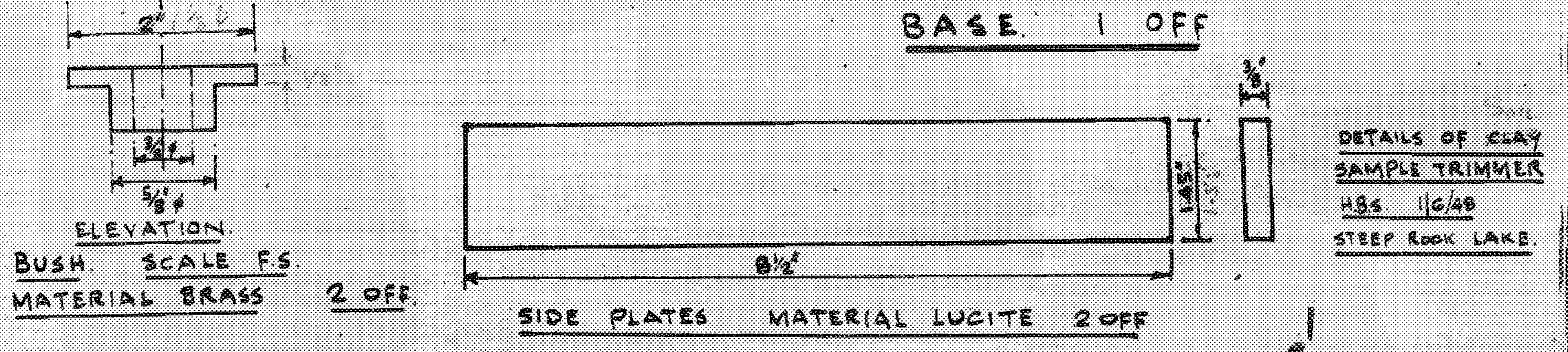
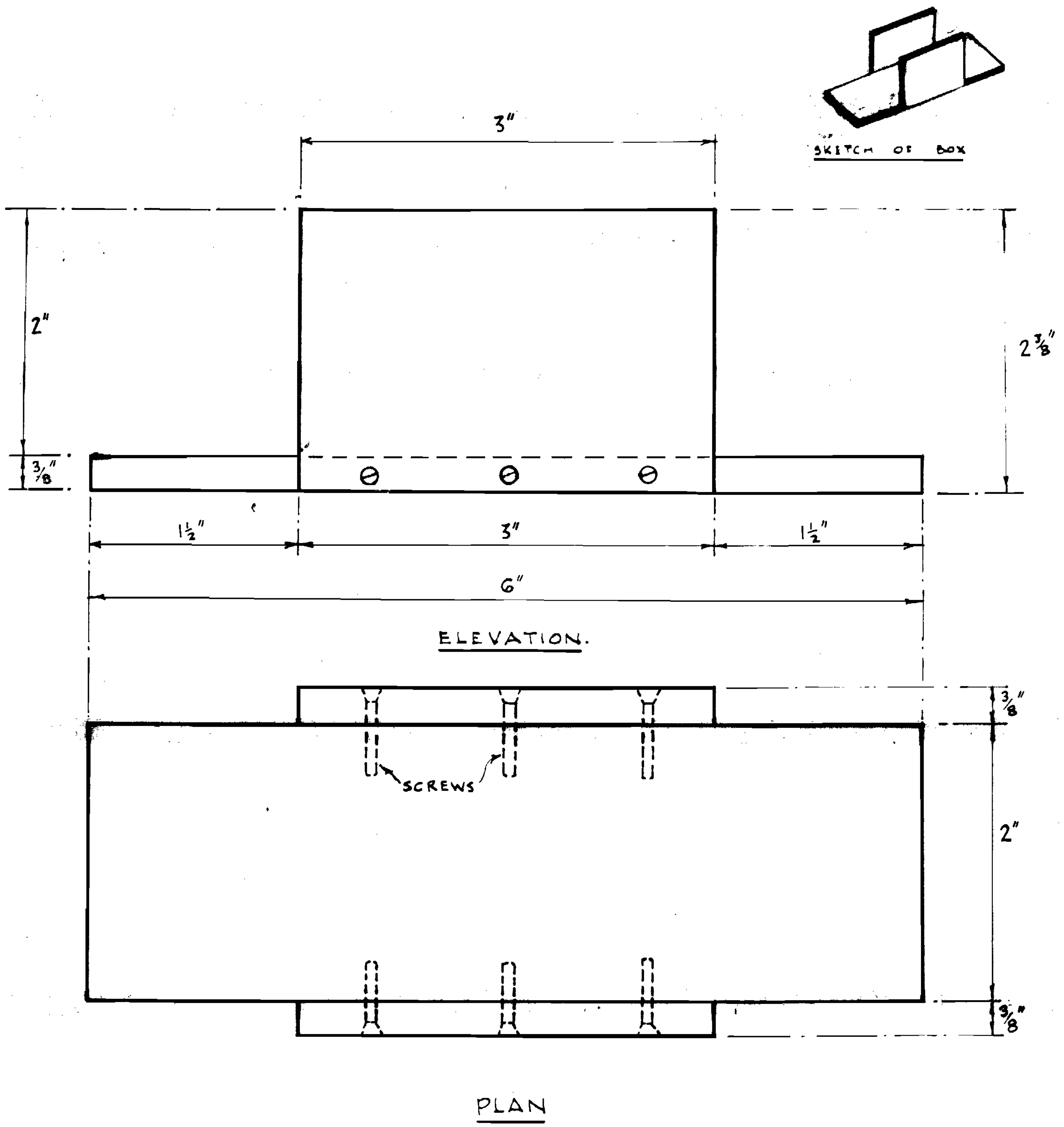

BASE 1 OFF
2"
3/8"
3/8"φ
5/8"φ
ELEVATION
BUSH SCALE F.S.
MATERIAL BRASS 2 OFF
1 5/8"
8 1/2"
SIDE PLATES MATERIAL LUCITE 2 OFF
DETAILS OF CLAY
SAMPLE TRIMMER
HBS 1/6/48
STEEP ROCK LAKE.

FIGURE 4



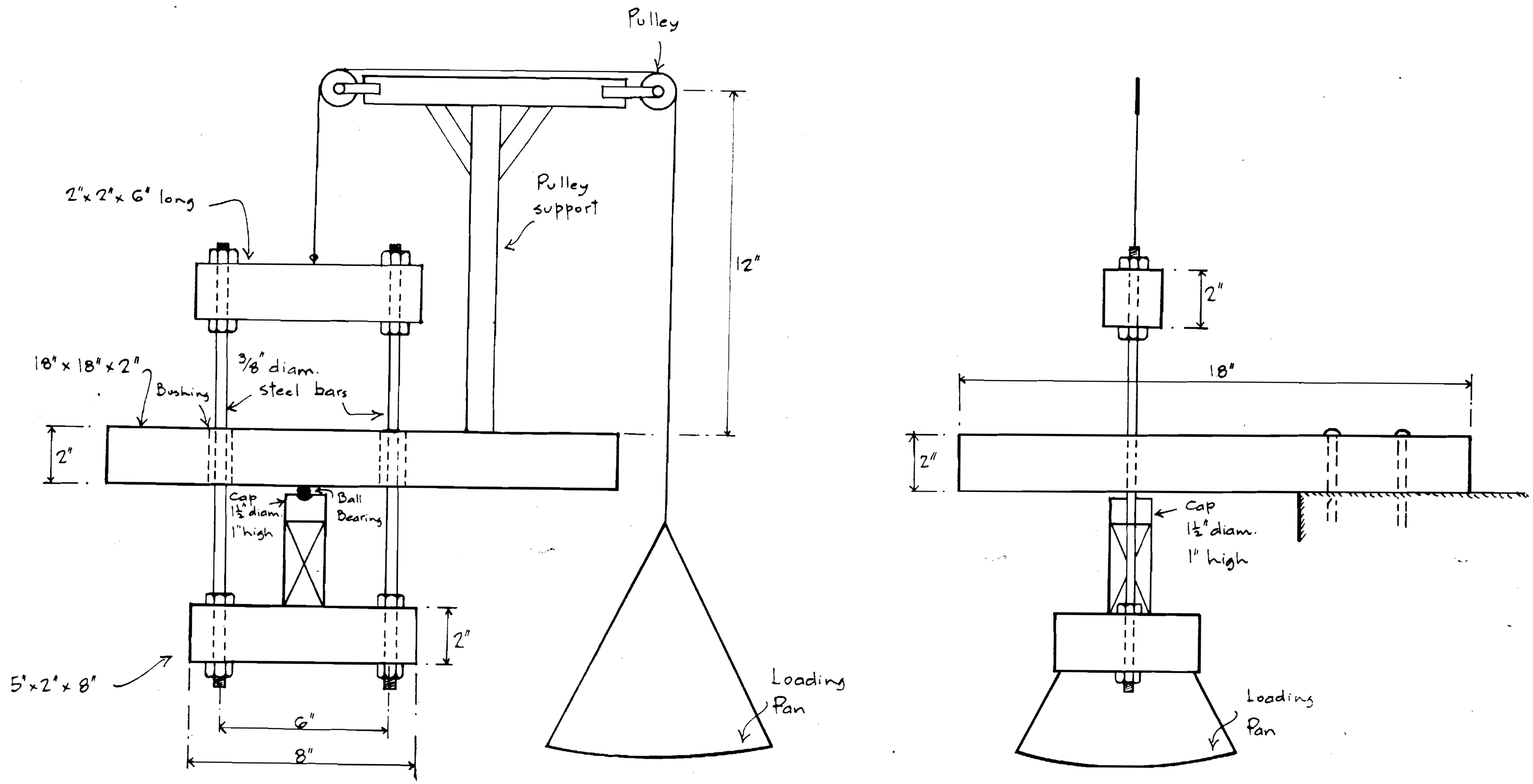
MITRE BOX FOR TRIMMING CLAY.

MATERIAL REQUIRED

BASE PLATE.	1 OFF	6" x 2" x 3/8"	LUCITE
SIDE PLATES	2 OFF	3" x 2 3/8" x 3/8"	LUCITE

H.B.S. 1/6/48
STEEP ROCK LAKE.
APPROX. FULL SIZE.

FIGURE 5



Requirements.

No.	Description	Size	Material.
1	Top Loading Bar	2"x 2" x 6"	Wood
1	Bottom Loading Bar	5"x 2"x 8"	Wood
1	Base Piece	18"x 18"x 2"	Wood.
2	Connecting bars.	3/8" diam 16" long threaded 3½" each end	Mild steel
1	Loading Cap	1½" diam. 1" long	Wood.
2	Pulley	1½" diam.	Steel
2	Bushing		Brass.
1	Pulley Frame		
	1 Loading Pan, 1 Ball bearing 1 Pulley string, 4, 3/8" diam. nuts.		

FIGURE 6.

SKETCH OF UNCONFINED COMPRESSION APPARATUS.

SCALE : ¼ F.S. 3" = 1'0"

Soil Mechanics Section
Division of Building Research
National Research Council
Ottawa.
Steep Rock Lake Ont. H.B.S.
1/6/48.

SUMMARY SHEET. UNCONFINED COMPRESSION TESTS ON VARVED CLAYS.

APPARATUS: CONTROLLED STRESS DIRECT LOADING PISTON TYPE.

TYPE OF SOIL: VARVED CLAYS FROM STEEP ROCK LAKE ONTARIO.

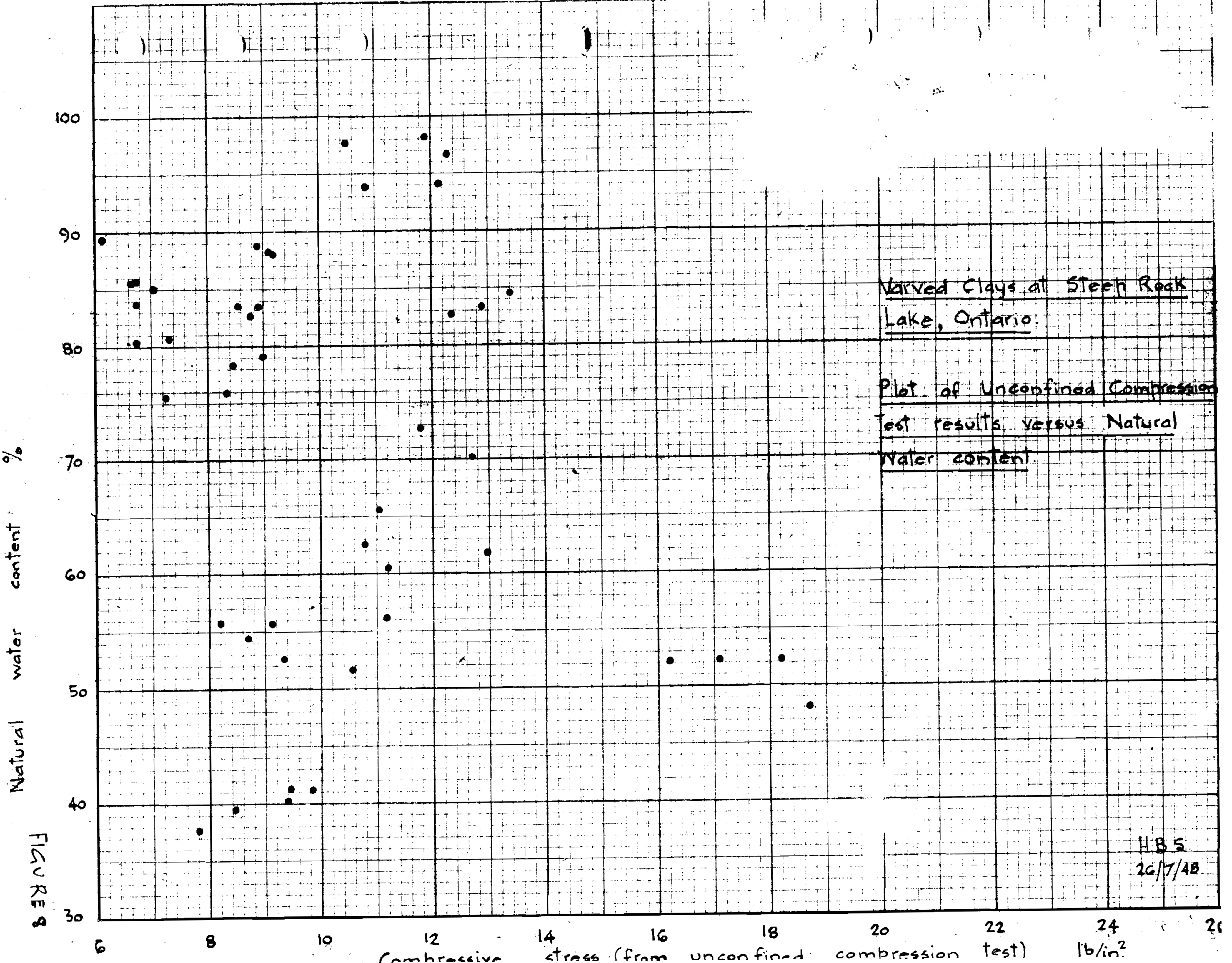
SPECIAL CONDITIONS: TEST SPECIMENS CUT FROM BLOCK SAMPLES LOADING APPLIED AT RIGHT ANGLES TO DIRECTION AND PLANE OF VARVES UNLESS STATED OTHERWISE.

Sample No.	Location and altitude above sea level	Dimensions of specimen inches.			Unconfined Compression strength lb/in²	Strain at failure %	Water content at failure %	Density in place lb/ft³	Measured angle of failure surface of failure to base of specimen	Sketch showing failure	Remarks
		Length	Side	Diameter							
23a	N 19002	2.95		1.4	9.45	9.5	41.3	–	65°		
23b	E 25400	3		1.4	9.40	8.7	40.3	-	70°		
23c	Elev. 1200	2.95		1.4	9.85	9.5	41.2		60°		
24a	N20294	1.4	0.8		10.58	12.8	51.6	105	70°		square prism
24b	E 23356 Elev. 1107	1.55	0.79		11.20	1.9	60.4	-	–	-	do.
24c		1.45	0.76		11.19	2.07	56.2	-	-	-	do.
25a	N20100	2.5		1.45	10.80	3.2	62.7		50° and 60°		
25b	E23510 Elev. 1110	2.5		1.40	11.02	2.8	65.6		70°		
25c		2.45		1.41	13.95	0.8?	61.9		65°		Test suspect Piston jammed.
26a	N20239	1.42	0.76		26.70	6.3	Dried out 47.8	-	-	-	square prism
26b	E24010 Elev. 1106	1.60	0.82		17.10	1.9	52.2	-	-	-	do.
26c		1.56	0.76		29.0	6.4	Dried out -	–	-	-	do.
26d		1.61	0.76		18.20	3.7	52.3	-	-	-	do.
26e		1.50	0.76		16.20	2.7	52.2	-	-	-	do.
26f		1.43	0.77		18.70	5.6	Dried out 48.1	-	-	-	do.
										stiff clay overlying boulder clay	
27a	N20058 E23638	2.96		1.40	9.15	3.4	88.0	105	65°		
27b	Elev. 1109	2.66		1.40	8.89	2.6	88.9	-	70°		
31a	N20018 E24883	2.70		1.43	12.35	3.0	82.8	100	65°		
31b	Elev. 1156	2.94		1.41	13.40	3.4	84.5	101	–		sample burst vertically.
31c		3.		1.40	12.90	2.7	83.4	101	55°		
32a	N 19991 E 24834	2.95		1.43	8.20	1.7	55.8	112	55°		
32b	Elev. 1144	2.50		1.40	8.70	2.8	54.4	–	-		sample burst vertically.
32c		3.		1.47	9.12	2.7	55.7	111	65°		
32d		2.85		1.42	9.35	4.9	52.6	-	-		sample burst vertically.
34a	N19850 E24830	2.95		1.40	8.78	3.4	82.7	101	60°		
34b	Elev. 1140	3.		1.40	9.10	4.0	88.4	-	65°		

35a	N 19300 E 24500	2.5		1.40	12.70	8.8	70.1	-	-	-	
35b	Elev. 1190	3		1.40	11.80	5.7	72.8	-	-	-	
36a	N 19010 E 25165	3		1.50	8.44	9.7	39.5	-	-	Bulge failure	Summer layers very sandy
36b	Elev 1209	2.90		1.41	7.80	18.9	37.8	-	70°		do.
37a	N19855 E 23670	1.7	0.682		12.30	5.3	96.8	102	-	-	square prism.
37b	Elev. 1125	2.95		1.41	12.15	3.7	94.1	-	55°		cylinder
37c		1.7	0.66		11.90	2.7	98.2	-	37.5°		square prism
37d		1.66	0.73		10.82	4.5	93.8	-	-	-	do.
37e		1.65	0.75		10.50	3.0	97.7	-	-	-	do.
											d
38a	N19585 E 25662	2.88		1.50	8.26	3.1	78.4	-	-	-	Loading right angles to varves
38b	Elev. 1182	2.75		1.50	7.35	2.5	80.7	-	-	-	do.
38c		2.63		1.50	6.74	2.3	80.3	-	-	-	Loading right angles to varves
38d		3		1.50	7.19	-	75.6	-	-	-	do
38e		3		1.50	6.74	2.0	83.8	-	-	-	Loading parallel to varves
38f		3		1.50	7.04	2.0	85.0	-	-	-	do
38g		3		1.50	6.74	1.7	85.8		50°		do.
39a	N19400 E25400	3		1.50	8.97	4.3	79.2	-	70°		
39b	Elev. 1190	3		1.50	6.63	6.0	85.7	-	70°		
39c		2.5	1.4		8.91	7.6	83.6	-	-	-	square prism.
39d		3		1.50	6.14	3.7	89.5	-	60°		
39e		3	1.4		8.34	7.3	76.0	-	-	-	

FIGURE 7

H.B.S. 30/7/48.



Varved Clays at Steep Rock Lake, Ontario.
Plot of Unconfined Compression Test results versus Natural Water content.
H.B.S.
26/7/48
Natural water content %
100
90
80
70
60
50
40
30
6
8
10
12
14
16
18
20
22
24
26
Compressive stress (from unconfined compression test) lb/in²

FIGURE 8