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AN EXPERIMENTAL STUDY IN
PISE' DE TERRE CONSTRUCTION
FOR WALLS OF DWELLING HOUSES

Thesis for the Degree of B. S.

Phillip L. Paine

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AN EXPERIMENTAL STUDY IN PISE'DE
TERRE CONSTRUCTION FOR WALLS
OF DWELLING HOUSES

A Thesis Submitted To

The Faculty Of

THE MICHIGAN STATE COLLEGE

OF

AGRICULTURE AND APPLIED SCIENCE

By

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Candidate For Degree Of Bachelor
Of Science

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Introduction.

Shortly after the War (1920-22), considerable interest was aroused, in the European Countries, in the building of pise'de terre houses. Many welcomed this idea with all the enthusiasm of revivalists, and claimed, in it, we would find the solution of our housing problem. They pointed to the houses of our early ancestors and claimed that with a few changes we might expect to adapt that type of construction to modern day needs.

Because of this interest, the Committee of the Privy Council for Scientific and Industrial Research, in England, appointed a Building, Research Board, in 1920; its chairman being "The Most Hon. the Marquess of Salisbury. The director of building research was Mr. H.O. Waller B. Sc.M.Inst.C.E. The purpose of this board was "to consider and direct the conduct of research on building materials and methods of construction."

About the same time as this board was carrying on its investigations, there were a number of investigations and experiments carried on in Germany, France, Spain, and New South Wales. However, the above mentioned board, together with "Experimental Cottages," a report on the work of the Department of Scientific and Industrial Research at Amesbury, Wiltshire, by W. R. Jaggard, seems to be the most complete investigations carried on in pise'de terre in Europe at the present time.

In the United States, interest in pise'de terre was not aroused until some time later. In 1926 Profs. Memfree and Franklin, both of the University of Michigan took up the study of pise'de terre. Articles appeared in the Eng. News Record (Vol 26-page 267) and also in the Scientific American (Vol-130-p-233) on "Rammed Earth," and "Houses of Mud," respectively. Others interested in the same subject being - J.D.Long, Ag. Eng.Dept., Davis Cal. and R. C. Miller, Ag.Eng.Dept. Fargo N.Dakota. About the most complete article, in regard to both the type of house suitable for pise'de terre construction and the construction itself is one in pamphlete form gotten out by the U.S. Department of Agriculture and is known as Farmers' Bulletin No. 1500 The article is entitled "Rammed Earth Walls For Buildings."

Pise'de terre construction is not a new idea. It has been gradually developed through out the ages. Probably the earliest form of habitation were built out of wattle work, consisting simply of interwoven branches and twigs with the leaves on. This was improved in pre-historic times by covering in earth and clay, or some other adhesive material. This process in England became known as daubing and the actual construction was spoken of as "wattle and daub." Such primitive construction probably entailed no end of repairs.

Bankart, in his "Art of the Plasterer" describes wattle and daub as follows:-

"_ _ _ _ Clay mixed with short straw and chalk was then worked in between the main timbers, thus covering the hurdle-like lathing with a rough 'daub' cement.

"Whilst still the clay was wet it was scored over to give keying to the finishing coat of lime plaster, which was itself colored and often painted with decorative designs on the inner surface."

Later, wattle and daub passed out of existence and cob took its place.

In a letter to "Country Life" (Nov. 22, 1913), Mr. Norman Jewson described the traditional way of making and using the cob as follows:-

"_ _ _ _ _ The cob is made by mixing clay and straw with sufficient water to get it to the right consistency. It is generally mixed at the edge of a pond, a horse being used to tread the clay and straw together. A course about a foot high is then laid on top of the base wall and well-trodden down, beginning at one corner of the building and following right right around, so that by the time this is finished, the cob first laid is hard enough to receive the next course and so on * * * * after the wall is brought up to the desired height, the surface is pared off and generally plastered. * * * *."

He also remarks that " * * * *With reference to cob cottages, which are well known to be comfortable to live in, and the materials for building which are generally abundant I believe there are few men to be found nowadays who will build them as cob-building is hard work and messy. * * * * *."

Mr. Tuycross in writing to the same paper at about the same time (Mar.14,1914) stated that until the year 1850 the entire town of Naseby consisted almost entirely of mud buildings and at the present time garden walls are still built in the same way. He also lamented the fact that there are few men left who can do this "mud-walling," and remarked that "houses can only be built where you have the right sort of tenacious mud."

An analysis of a piece of typical Devon cob for Mr. A. Alban H. Scott gave the composition as follows:-

	Per.cent.
Stones (residue on 7x7 mesh sieve)	24.40
Sand, Coarse (residue on 50x50 mesh sieve)	19.70
Sand, Fine (through 50x50 mesh sieve)	32.50
Clay	20.60
Straw	1.25
Water	1.55
	<u>100.00</u>

Pise'de terre or the system of building with earth rammed between boards, has deservedly received more attention than Cob in recent years as being a fitter method for revival and adaption to modern conditions. It must not be confused with

either of the two foregoing discussions of daub and wattle, or cob. Although pise'de terre is not intended to replace cob it is far more adaptable to our needs than any other "Earth Houses."

Some people have thought that pise'de terre is the modern solution of our housing problem. Others, refusing to admit any good points about it, jestingly refer to it as "Castles of Mud". From the scientific standpoint, this type of construction can be said to be in its infancy yet. From past experiences and experiments however, indications are such that might lead one to think that with more time and effort on the part of the engineering world, something of commercial value to the present methods of building may be added.

There are a number advantages already proven for pise'de terre construction. There is ample proof that thoroughly sound and durable walls were constructed on the most ancient of pise'de terre systems.

Plivy in his "Natural History", comments on the strength and lasting qualities of "formocion" walls, "moulded, rather than built, by enclosing earth within a frame of boards."

Failures were no doubt common, but were probably due in most cases to causes that could be avoided in modern work.

Those who have followed the lead of Mr. St. Loe Strachey, the revivalist of the method in England, and whose work is described in "Cottage Building in Cob, Pise'Chalk and Clay," by Mr. Clough Williams-Ellis, have progressed a long way towards the elimination of such causes. With the more efficient types of shuttering now available, there is no real restriction of plan. There are perhaps more limitations to such a method than to one employing a small unit of construction, but any good straight forward plan should be workable.

For maintaining an equable temperature within, pise' walls are hard to beat; they make the most comfortable of dwellings in summer or winter, and excellent stores for produce or materials affected by excessive heat or cold.

Costs depend so largely on local conditions that it is practically useless to state a relationship between costs of pise'de terre and other building materials. However it is quite safe to say that whatever the conditions are, pise' construction will cost about (2/3) two thirds of the cost of a similar building in brick or stone.

As one readily sees, in reading that which has been done in pise' de terre construction, there has been no method by which a person, wishing to use this method of construction, can pre-determine the strength

he can reasonably expect the soil on his property to attain. A person of limited means might very well hesitate then to expend much time and money on a thing that he could not be reasonably sure of standing after it was built. The purpose of this thesis, therefore, is to study the strength developed in pise'de terre walls and to determine if possible some simple tests to pre-determine this strength.

Outline of Experiments.

In this study of pise'de terre construction there are four results hoped to be attained by experiment. First, to determine whether the strength of pise'de terre is due to just the ramming of the earth, to the clay acting only as a binder, or is due partly to the actual strength of the clay. Also to derive a curve showing the compressive strengths that can be developed by variable amounts of sand and clay. Hereafter this test will be known as test number one.

Second, taking a sample of soil, run the tests developed in test #1, make test cylinders and break the same in a compression machine and check the actual strength with the strength from the curve of test #1. This experiment will hereafter be listed and spoken of as test number two.

Third, making two sets of three cylinders each, both sets having the same composition, to dry one set with artificial heat and the other set to dry naturally, determine whether any strength is lost due to rapid drying. This test will be known as test number three.

Fourth, to build a small model house, to use both for exhibition purposes and also to expose to the elements in the study of waterproofing and paints to be used in this construction.

Method of Procedure.

Test No.I.

In order to make a comparison between two substances of different composition, we must have some standard of comparison. The standard in this case was a ratio expressed between the voids in a sample and its clay content. In other words a voids-clay ratio was the standard by means of which all samples of earth were to be compared.

This particular ratio was chosen to see whether or not the clay in the pisé-de terre construction does not have the same function as the cement has in concrete construction. What is does it not serve merely as a binder?

Talbot's method of proportioning concrete has data showing that the strength of concrete is dependent upon the ratio of the volume of voids to the volume of cement.

If then, the clay in pise'de terre construction, plays the same part as cement in concrete construction, the rammed earth will have strength dependent on the ratio of the volume of voids to the volume of clay in the soil.

Talbot's method of proportioning concrete is identical with the water ratio theory of proportioning concrete when the voids in the concrete are entirely filled with water. To-day, the water ratio theory of proportioning concrete is thought to be the most scientific way of mixing concrete. Therefore, since the water has nothing to do with the strength of rammed earth, and since the amount of water is the only difference between Talbot's method and the water ratio method of proportioning concrete, why is it not logical to assume that the voids-clay ratio will determine the strength of pise' de terre walls? If such an assumption is correct, a curve, drawn with the compressive strength as ordinate and the voids-clay ratio as abscissa, should drop off or at least not rise any higher, when the voids-clay ratio reaches 100%.

Therefore in determining whether the clay in pise'de terre construction acts only as a binder or

whether it has an actual strength of its own, test cylinders were made of pise' de terre in which the voids-clay ratio was varied. These cylinders after being thoroughly dried, were broken in a compression machine. Their actual strength was recorded. This value was plotted against the voids-clay ratio of the cylinder.

The cylinders were considered thoroughly dry when they assumed a constant weight.

The test cylinders were made of sand in which some gravel was mixed, (gravel varied up to the size of a walnut). The sand and gravel was mixed mechanically with clay from a Lansing brick yard clay pit. The clay was pulverized before using.

The percentage of voids in the sand and gravel was determined first. The following method was used. A known volume of sand and gravel was weighed. (Weight A). The container partly filled with sand was then filled to overflowing with water and weighed. (Weight B). The container filled to overflowing with water alone was weighed. (Weight C). In each case the net weights were used. Using the letters to represent the weights, the following formula will give the absolute volume of the sand and gravel.

$$\frac{B-(A \times C)}{62.4} = \text{absolute vol. of sand and gravel.}$$

Then letting x = apparent volume of sand,
and Y , the absolute volume of sand, the formula,

$$\frac{100 (x - Y)}{x} = \% \text{ of voids in the sand and gravel.}$$

In order to proportion the various mixtures of sand and clay by weight instead of volume, a ratio between equal volumes of dry and rodded sand, and dry and rodded clay was needed. In this particular sample the sand was 1.43 times as heavy as the clay. Therefore, if a voids-clay ratio of 50% was desired, when there was 20 pounds of sand which had a volume having 30% voids, the following computation would give the correct weight of clay to be used.

30% of 20#s = 6# clay to fill 100% of the voids.

$$\frac{50 \times 6\#}{100} = 3\# \text{ (clay to fill 50\% of the voids, (if the clay and sand were equal (in weight.))}$$

$$\frac{3\#}{1.43} = \begin{cases} 2.28\# \text{ clay needed to fill 50\% of} \\ \text{the voids in the sand when the} \\ \text{sand-clay weight ratio} = 1.43. \end{cases}$$

The foregoing is an example of the steps necessary to proportion a set of test cylinders. Each set was comprised of three cylinders. In this test eleven sets of cylinders were made having the following voids-clay ratios:

4.1%; 12%; 20.45%; 40%; 50.8%
75%; 102.4%; 125%; 150%; 175%; 200%.

The materials (sand and clay) that went to make up a set of test cylinders were thoroughly mixed while dry. Then water was added gradually until the mixture was damp enough to hold together when a handful of it was compressed. The least water used to obtain a workable mixture, the easier it is to ram the earth solidly in the molds. If too much water is used, instead of compacting, the earth will just squeeze up around the rammer. If such a condition should arise, add a little more earth or else allow the mixture to stand long enough to dry a little before placing in the molds.

The molds used were made of three-ply cardboard, well paraffined. They were cylinders having a three and one quarter inch diameter, six and one half inches in height.

The dampened soil was placed in the molds and rammed with the peen end of an ordinary foundry rammer until the earth sounded solid. Another layer of earth was added and rammed and so on until the mold was filled level full. In the last few layers the ramrod was replaced by a two and one half inch wooden mallet which was held in the mold and struck with a heavy hammer.

Due to the fact that the molds had to be torn from the rammed earth, the cylinder was allowed to stand twenty-four hours before its mold was stripped from it. In this way there was not as much danger in breaking the cylinder due to the tension in pulling the

The cylinders were then allowed to dry until the sets containing the moist clay assumed a constant weight. They were then ready to be broken in a compression machine.

Before breaking, however they were capped in plaster-of-paris to evenly distribute the pressure over the entire area of the cylinder. Some of the cylinders which were low in clay could not be capped due to the fact that the moisture from the plaster-of-paris would get into the cylinder and cause it to crumble. They were broken without being capped. In the latter cases soft card board was used in place of the plaster-of-paris caps.

The data collected, together with the curve of the compressive strength plotted against the voids-clay ratio, will be found in another part of this report listed under "Data" and also "Results and Conclusions."

Method of Procedure.

Test No.2.

As was stated in the outline of tests, this test was to develop some experiments to determine the voids-clay ratio of a sample of earth. It was also to take a sample of earth of unknown composition, to run these tests on the sample and then determine its strength from the curve of Test No. I. Also, it was to take this earth and make test cylinders, and break them after being cured as in Test No. I. This procedure gave two values, which should check fairly close, for the strength of the earth.

This test resolves itself into two sections, first, to determine the voids-clay ratio and second, to make the cylinders, and break them to find their actual strength.

The first section has two parts viz., getting the sand-clay-weight ratio and second actually determining the voids-clay ratio.

To determine the sand-clay-weight ratio.

1st. Weight a sample of earth, and measure its volume.

2nd. Wash the clay from the earth by the following test:-

Break up all sand and clay lumps with a mortar and pestle, being careful not to break the rock fragments. Pour the mixture into a one liter beaker in which stands 8 con. of ammoniated water of a concentration of 1:500.

Allow the mixture to stand for eight minutes, and then pour off the supernatant liquid. Repeat this process until the liquid, after standing eight minutes is clear. The clay has now been washed out and the sand and silt alone remains in the beaker.

3rd. Weigh the contents of the beaker, and measure its volume, when dry.

4th. The difference in the two weights is the weight of clay.

5th. The difference in volumes is the volume of clay in excess of enough to fill the voids in the washed sand and silt.

6th. Determine the percentage of voids of the sand and silt without the clay.

7th. Multiply the volume of sand and silt (3rd) by this % of voids, which gives the volume of clay necessary to fill 100% of the voids.

8th. Add this volume (7th) to the volume of the (5th) step which will give the total volume of clay in the sample.

9th. Divide the weight of clay (4th) by the total volume of clay (8th) to give the unit weight of clay.

10th. The weight of sand and silt (3rd) divided by its volume, also the (3rd) gives the unit weight of the sand.

11th. Divide the unit weight of the sand (10th) by the unit weight of clay (9th) to give the sand-clay-weight ratio.

The second part, to determine the voids clay ratio, is as follows:-

- 1st. Multiply the total volume of sand and silt by the percentage of voids as determined in the 6th. step of the first part.
- 2nd. Multiply this volume by the unit wt. of sand, giving the wt. of sand necessary to fill the voids.
- 3rd. Divide the above weight by the sand-clay-weight ratio, which will give the weight of the clay necessary to fill 100% of the voids.
- 4th. Divide the weight of clay in the sample as derived in the 4th. step of the first part. This value multiplied by 100 is the voids-clay ratio.

In the second section of Test No. 2 the cylinders are prepared in the same manner as for Test No. 1. and are broken in the same manner. See the data sheet for computations and results.

Method of Procedure.

Test No. 3.

This test, which was to determine if the rapid drying out of the pise' de terre would cause it to lose some of its strength, was carried out in the following manner.

In test No. I. there was a set of cylinders having a voids-clay ratio of 102.4%. These were duplicated by another set of three cylinders of the same composition, the same amount of ramming and the same moisture ^{content} ~~contact~~. The first three cylinders were drying naturally for Test No. I. The second set were placed close together in a single row. A bunsen burner was placed on each side of the row and a reflector placed back of each burner to cast as much of the heat toward the cylinders as possible. The idea of this arrangement being to get a condition as near as possible to what a person would have if he wanted to hurry up the drying of his walls of pise'de terre by building a fire on each side of the wall. The purpose of this test being, as was previously stated, to determine whether or not the rapid drying process was detrimental to the strength of the pise'de terre construction.

The data and results of this test will be found listed as such in a later part of this report.

Method of Procedure.

Test No. 4.

As was stated in the outline of tests, this test is to build a model house of pise'de terre. The purpose of this is two-fold. First, the primary reason is to leave something tangible, besides a mere report, to interest some student in the further study of pise'de terre construction. Second the house was painted with ordinary paint and is to be exposed to the rigors of a Michigan winter. Naturally, with two such purposes in view, no results or conclusions will be found in this report. The report will only include a method of building the house along with a simple drawing or plan of the same.

In the first place the house is not a "Model" in the sense of being perfect as to design or construction. The word "Model" as used in this report only means the building of a house on a small scale. All sizes and dimensions can be found in the blueprints found with the "Results and Conclusions" of the previous tests, in the final pages of this report.

The first step in the building of the house was to build a foundation. Due to the small size of the structure, neat cement was used instead of concrete. The foundation was anchored to the supporting platform by nails having been driven into the platform and the

cement hardening in place around them.

As soon as the cement had begun to harden a keyway was cut into it and then nails were driven into the keyway. This was to bond the earth to the foundation.

The forms for the walls were then built. Ordinarily the forms for this type of construction are only three feet high and eight feet long. The walls are generally built by ramming this section and then moving the forms forward and ramming a second such section and so on until a course three feet high is completed around the entire house. Then the forms are raised and a second course is built in the same way on top of the first and so on until the entire wall is built. A very good detailed account of this construction can be found in the pamphlete "U.S. Department of Agriculture - Farmers' Bulletin No.1500" under the title "Rammed Earth Walls For Buildings."

Because of the lack of rigidity in forms built on a very small scale, the forms for the model house were built in the form of the entire house.

The forms were placed on the concrete foundation and the earth rammed between them. The window and door casing had a precast layer of cement around them. This was to protect the earth around the windows and doors from getting wet due to water soaking thru the wooden sills.

The window casings and doors were rammed into place and the walls built up to the required height. On top of the walls, a layer of neat cement was placed for protection as in the case of the windows and doors. Before the concrete set, a wooden nailing strip or sleeper was put into the cement, the sleeper being flush with the top of the cement. The roof was nailed to this sleeper. The roof was made of "homosote."

No attempt was made to design the house for anything except to make it water tight and weather resisting. A "Model" house as to design and construction would be enough alone, for another thesis.

The house was given three coats of ordinary house paint after it had the appearance of being dry.

A detailed plan will be found at the end of this report showing all the details that were introduced in the construction of this model.

Data Sheet.

Test No. 1.

Cross sectional area of cylinder = 8.3 sq.in.

CYLINDER NO.	VOIDS-RATIO	CLAY: TOTAL PRESSURE	#s/sq.in.	TONS PER sq.ft.	APPEARANCE
		#s.			(Fell to
1	4.1 %				) pieces when
2	4.1 %				(molds were
3	4.1 %				) taken off.
4	20.45 %	280	33.8	2.44	(
5	"	220	26.5	1.91	) Very granular.
6	"	230	27.7	2.0	(
7	50.8 %	675	81.4	5.86	) Still quite
8	"	775	93.4	6.73	(sandy but sub-
9	"	615	74.2	5.35	) stantial look-
10	102.4 %	1297	156	11.25	ing. (Looks like a
11	"	1242	150	10.81	) poor grade of
12	"				(concrete.
13	75 %	1090	131	9.45	) Quite compact,
14	"	980	118	8.5	(sand does not
15	"	910	110	7.94	) loosen when
					(handled.
16	12 %	100	12	0.86	) Hardly held
17	"	95	11.5	0.83	(together
18	"	110	13.25	0.96	)
19	40 %	540	65	4.7	(More compact
20	"	665	80	5.76	) but still quite
21	"	420	50.5	3.64	(granular.
22	125 %	1280	154	11.1	) About the same
23	"	785	94.5	6.8	(as the 102.4%
24	"	1395	168	12.1	) cylinders
25	150 %	1100	132	9.5	(Very compact,
26	"	845	101	7.27	) slight
27	"	1125	136	9.8	(cracks.
28	175 %	1255	151	10.8	) Full of hair
29	"	1140	137	9.87	(like cracks.
30	"	1095	132	9.5	)
31	200 %	1250	151	10.8	(The excess clay
32	"	1220	147	10.6	) seems to have
33	"	1225	147.5	10.65	(segregated

Data Sheet.

Test No. 3.

CYLINDER:VOIDS-CLAY:TOTAL		#s/sq.in.:		TONS PER :	
NO.	RATIO	PRESSURE:		sq.ft.	
		#s.			
1	102.4%	1297	156	11.25	{ <u>Naturally Dried.</u>
2	"	1242	150	10.31	
3	"		:Cylinder was broken) :in stripping mold. (		
4	"	1090	90.4	6.5	{ <u>Heated.</u>
5	"	580	48.2	3.5	
6	"	840	69.7	5.02	

The heated cylinders developed some cracks in the walls closest to the fires. They also had a more granular appearance.

RESULTS & CONCLUSIONS

TEST NO. I.

The outstanding result of test No. I. is that the clay apparently has no strength of its own. It only acts as a binder for the sand and gravel in the mixture. This is shown by the voids-clay ratio curve dropping off after it passes the 100% point on the curve.

Another outstanding feature taken from the curve, is that an excess of clay seems to cause very erratic results. The value of the strength at the 200% point was not shown on the curve, ^{*This value is now shown*} but the data sheet shows that its average was higher than the 175% point. The appearance of the 175% and 200% cylinders may throw some light on this point. Although the sand and clay was thoroughly mixed while dry, after moistening and ramming, the particles of excess clay seemed to have greater cohesion than adhesion, causing a segregation of the sand and clay particles. This condition evidently caused weak spots in the test cylinders. The cylinders having the greatest segregation, evidently, would be the weakest cylinders.

The cylinders of this test did not stand up under as great pressures as some made at the University of Michigan. There might be two reasons for this; either the amount of ramming, or the tenacious qualities

of all clays, might not be the same. The cylinders at the University of Michigan were rammed with a pneumatic hammer until they sounded solid. The cylinders of this test were rammed by hand until they sounded solid. Two individuals might not agree on this solid sound. The other reason would call for a test of all clays possible, and then classifying them by the use of some standard test such as the "Capillary Potential Test".

The above two reasons suggest two lines along which further study might be of benefit to this type of construction. First to determine just what part, the ramming of the earth plays in this construction. To do this, make a set of cylinders in which the composition was held constant. Strike the cylinders with blows of equal intensity but vary the number of blows. Allow the cylinders to dry and break them in a compression machine.

Second - Get as many samples of clay from all parts of the country as possible. Make test cylinders holding the quantities of ingredients constant but using different kinds or qualities of clay. Plot the compressive strengths developed against the capillary potential of the clay sample.

If the above tests proved successful, their use along with the voids-clay ratio curve, would give

worlds of information to the timid and conservative home-builder, who did not want to risk his money on a venture in which he had to guess at the results he could get from the soil on his particular property.

COMPRESSIVE STRENGTH IN LBS./SQ. IN.

200
160
120
80
40

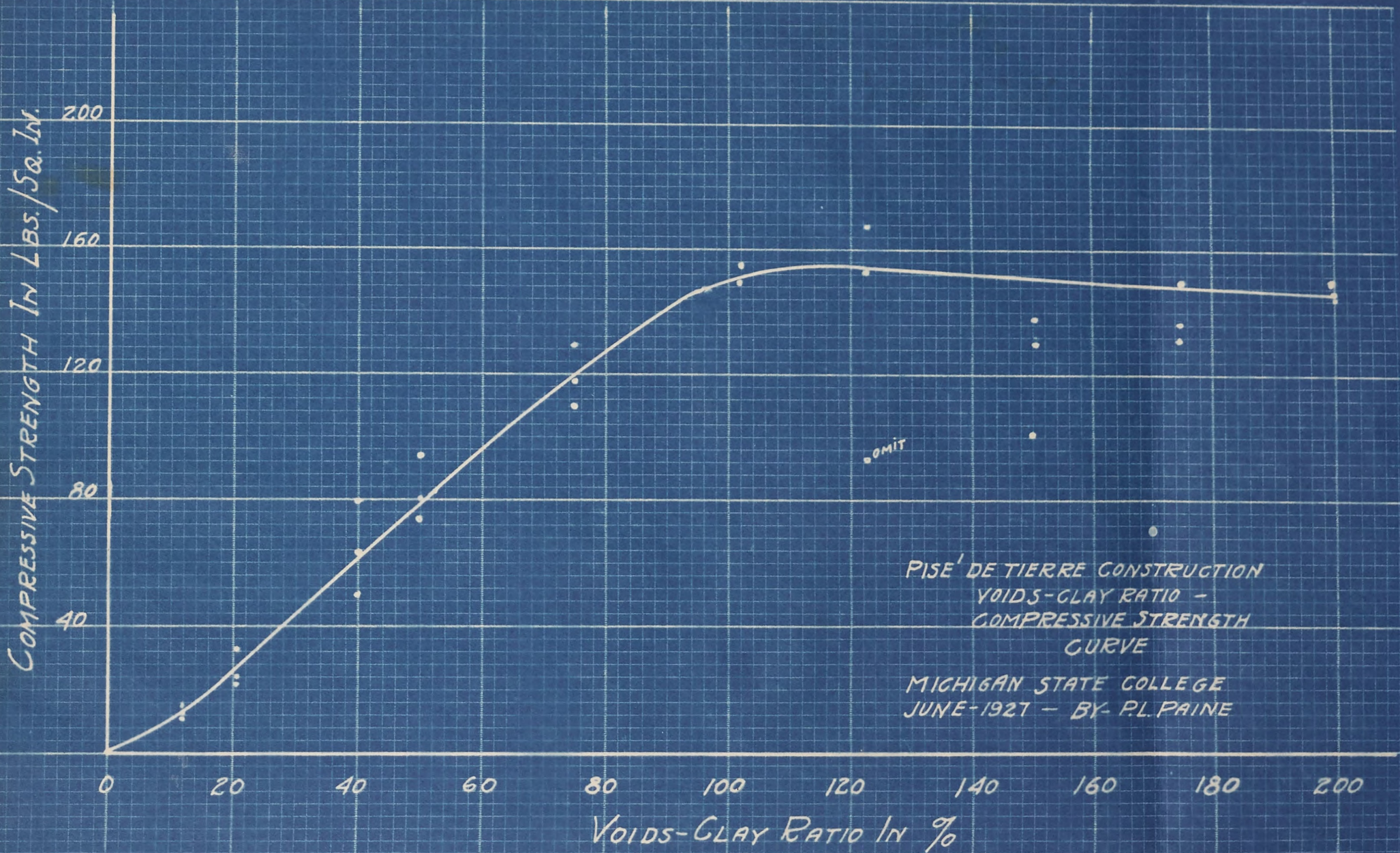
0 20 40 60 80 100 120 140 160 180 200

VOIDS-CLAY RATIO IN %

PISE' DE TERRE CONSTRUCTION
VOIDS-CLAY RATIO -
COMPRESSIVE STRENGTH
CURVE

MICHIGAN STATE COLLEGE
JUNE-1927 - BY PL. PAINE

omit



RESULTS & CONCLUSIONS.

TEST NO. II.

The curve gives a value of 148 lbs. per sq. in. for a soil having a voids-clay ratio of 170%. The lowest cylinder actually broke at 159 lbs. per sq. in.

It was rather unfortunate to have tested a soil above 100%, as the curve has not as even a slope after passing the 100% point.

The values of the original test cylinders were very erratic between 125% and 175% so the result of this test is quite satisfactory. However before any real conclusions could be drawn, a number of check tests should be run checking the curve at various points.

This test checks with the first test in showing that there is a relationship between the compressive strength of earth and its voids-clay ratio. It tends to further prove that the clay acts only as a binder and does not lend any of its own strength to the mixture.

RESULTS & CONCLUSIONS.

TEST NO. III.

The data for test No. 3 shows that when cylinders are dried by artificial heating, eradic results are liable to be attained. Therefore unless a person could constantly guard the fires he was drying his walls with, he might better allow them the time necessary to dry naturally. By careful, slow, heating good results probably could be attained, but it evidently would not do to just build the fires and allow them to run their own courses.

Fast drying caused cracks to appear in the outer walls of the cylinders which would cause both weakness and deterioration due to climatic conditions. The cracks were due to shrinkage caused by the rapid loss of moisture.

RESULTS & CONCLUSIONS.

TEST NO. IV.

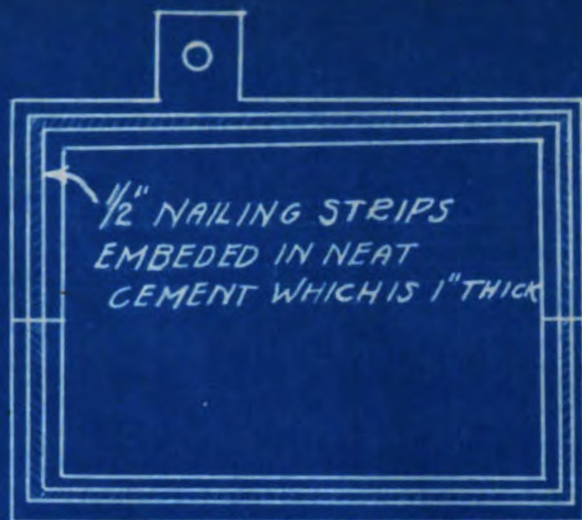
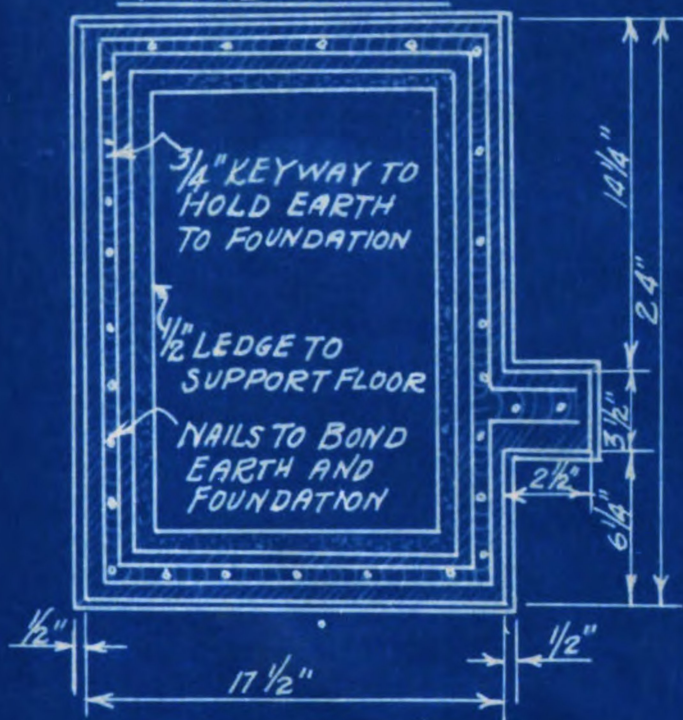
As has already been stated, no results can be stated for this experiment at this time. The condition of the model house at the end of a winter season will be a convincing report of this test.

The plans and details of the house are shown in the accompanying drawings.

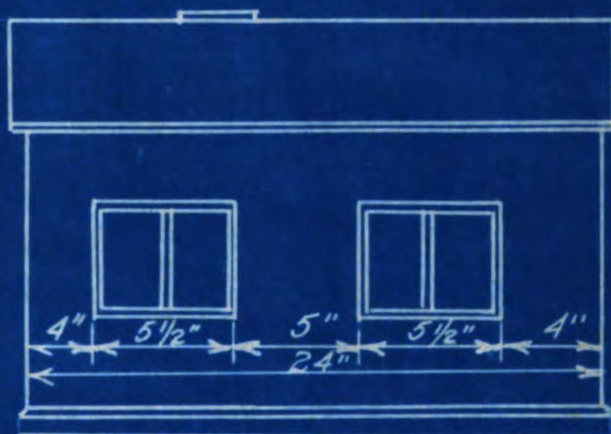
MODEL HOUSE
PISE' DE TERRE CONSTRUCTION
BUILT IN CONNECTION WITH
THESIS WORK FOR B.S.

DEGREE
SCALE - $\frac{1}{8}" = 1"$ - DATE - JUNE 1927
BY P.L. PAINE

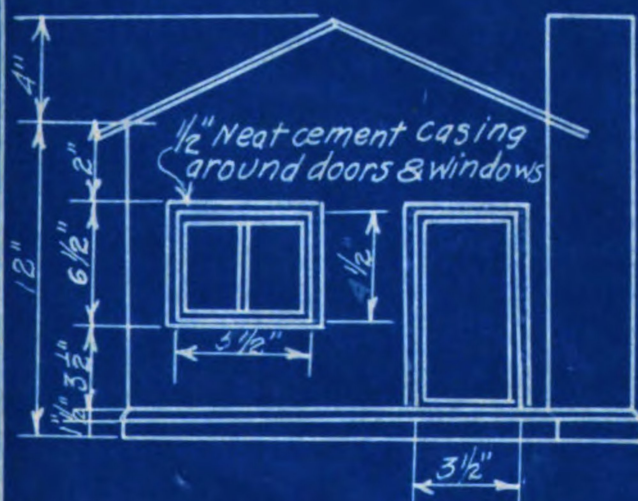
NEAT CEMENT
FOUNDATION



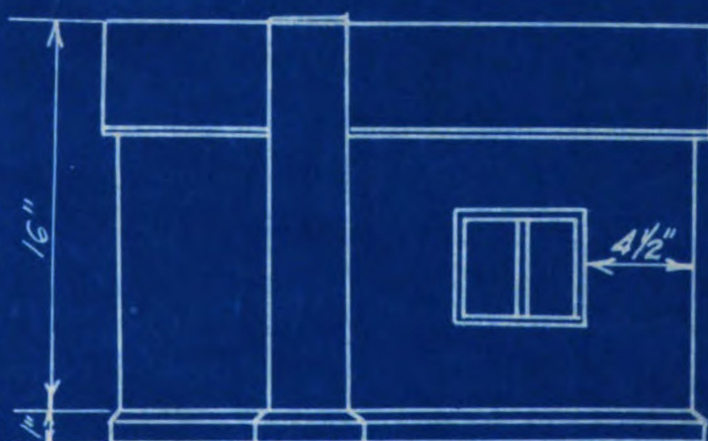
TOP OF WALLS



SIDE ELEVATION



FRONT ELEVATION



SIDE ELEVATION

NOTE - ALL WOODWORK IS OF $\frac{1}{2}"$ LUMBER
ALL WINDOWS ARE SAME SIZE

Summary of Thesis.

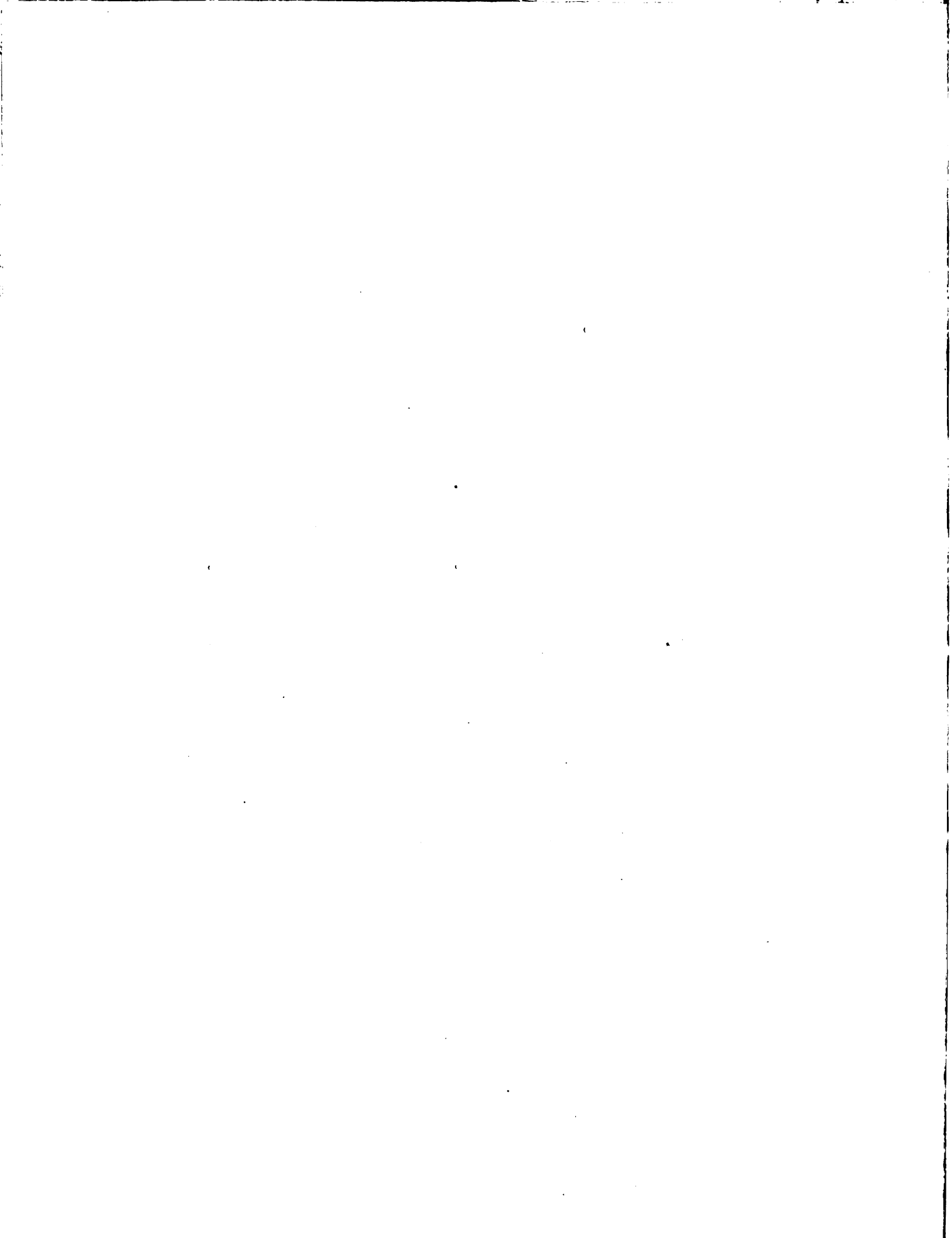
Pise' De Terre construction, although an old idea in itself, needs to have engineering principles, and practices added to it in order to be of much use to the present building situation.

The houses are decidedly comfortable to live in, both in summer and winter. The labor in building constitutes their biggest item of expense. The materials must be found on the property, or site of erection, in order to make the finished house cheaper than any other house. When materials have to be hauled in to get a soil of the right consisteney, an ordinary frame house would be just as cheap.

Here-to-fore there have been no tests derived to pre-determine the strengths of various soils. The object of this thesis, primarily, was to try and develop some such tests.

Starting with the same idea as is used in proportioning concrete and assuming that the clay performed the same function in pise' de terre construction as the cement does in concrete, tests were run to check both the idea and the assumption.

Of course, no set rules or empirical formula, should be accepted without their results being checked by a number of tests. The time element limits this experiment to a single check. This check seems to be



quite satisfactory, the curve being on the conservative or safe side. However the curve should be checked in a number of places before it is either accepted or rejected.

The tests themselves suggested the following lines of further study in Pise'De Terre construction.

- I. How much of the strength of construction is due to ramming.
- II. Will different clays give different results?
- III. Does the size of gravel or stones make any difference in the results.
- IV. How long does it take to gain its full strength. Show the gain in strength from day to day by a curve.
- V. Devise some way to make paint adhere to the surface of the walls.
- VI. Design a model house which is a model both as to design and construction.

The results of the tests performed were of such nature as to need considerable more study but at the same time they tended to prove that it is possible to predetermine the strength that soil can develop without actually making test cylinders and waiting for them to dry for four or five weeks.

If the soil is of the right composition, a substantial and cheap house can be built of pise'de terre. If materials have to be brought in pise'de terre loses its advantage. Pise'de terre of necessity must be simple in design and constructed of local materials.

1990-1991

[illegible]

SIDE ELEVATION

NOTE-ALL WOODWORK IS OF 1/2" LUMBER
ALL WINDOWS ARE SAME SIZE

FRONT ELEVATION

1/2" Neat cement casing
around doors & windows

„2/

2/5

← 3/4

 $5\frac{1}{2}$

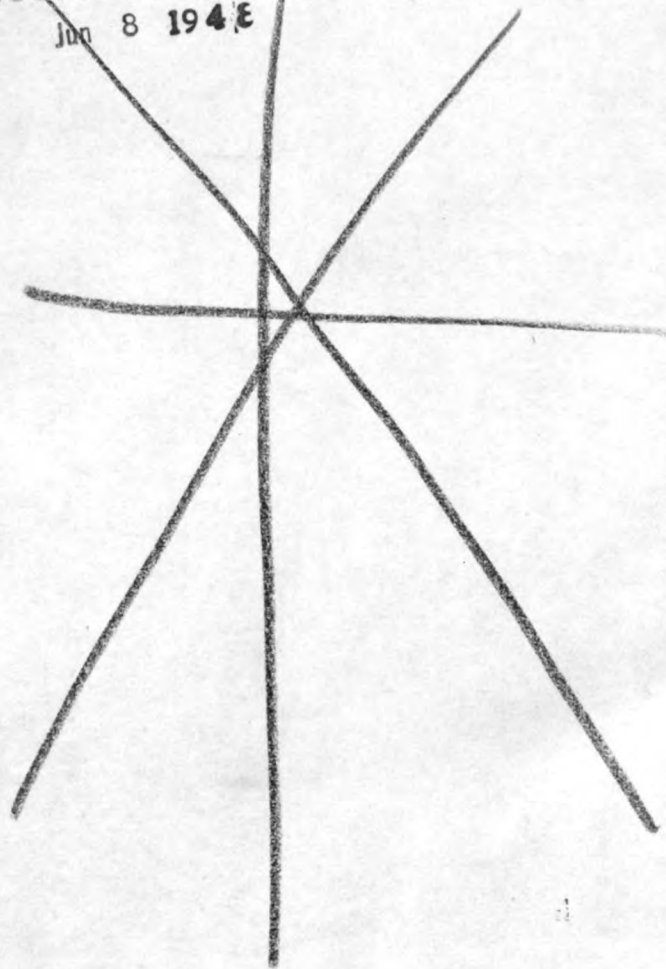
„91

 $\frac{1}{2}$

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