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Pressure transmission in clays affected by time of pressure application

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PRESSURE TRANSMISSION IN CLAYS AFFECTED BY TIME OF PRESSURE APPLICATION

BY

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THESIS

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PRESSURE TRANSMISSION IN CLAYS AFFECTED BY TIME OF PRESSURE APPLICATION

Introduction

Experienced dry-press operators have long known that when they slow down their presses, to the proper speed they are able to exert more pressure on a wetter mix with out pressure cracks becoming apparent. When a clay mix is compressed in a dry-press there is a gradation of the pressure exerted, from the rams to the center, causing in some cases a soft centered brick. "Shelly brick", are undersirable because they do not have uniform physical properties through out. This weakens their structure, due to unequal stresses developed in drying and fireing. The defective structure of dry-pressed brick has been attributed to many other causes, such as uneven moisture distribution, improper grain size gradation, grain size segregation, occluded air, plasticity of the mix, degree of pressure, and rate of compression. All of these factors have their effect on pressure transmission in one way or another, consequently we attribute the imperfect structure of some dry-pressed ware to inadequate and non-uniform pressure transmission to all parts of the ware.

A review of the literature discloses no information or data pertaining to the effect of variation of time of applied pressure on dry-pressed ware. It is, therefore proposed to make a study of the effect of variation of time of applied pressure on pressure transmission in dry-pressing.

The Test for Pressure Distribution[1]

If the pressure were extremely high, even pressure distribution would approach a maximum, also the thinner the brick becomes the closer this property of even distribution of pressure approaches a maximum. It was, therefore, decided to use a block which was about ten inches in thickness after a pressure of 2000# was applied, as the thicker the column of clay the larger the variation in physical properties from top to bottom.

The method used was the seperation of the block into layers and the apparent porosity of each layer obtained. This would indicate the degree of compression vertically through out the brick. The column was seperated into layers by the use of potters flint, which was sprinkled between each layer in building up the block. Each block contained eight layers, which were 2" thick before compression, and approximately 4# of clay was used in each layer depending upon the density of the mixture. The flint allowed the layer to be seperated after forming due to the low bonding power of the dry flint. Each layer was then quarted and the app-

1 Buletin No. 109, NATIONAL BRICK MANUF. ASS. 10-1-'30.

arent porosity determined on the two diagonally opposite quarters.

PROCEDURE

Grinding

Each of the clays in the different mixes were subjected to dry pan grinding in a three foot convertable wet and dry pan running at a speed of 60 r.p.m. The screen plates used in the pan had openings 1/8 inch in width and 5 inches in length. Grinding was continued in each case untill the entire sample passed thrugh the screen mesh desired.

Mixing

Mixes 1 and 2 were screened through a 10 mesh and 3,4, and 5 through a 8 mesh screen. The great Weastern Manufactureing Co. gyratory Riddle was used in each case.

Tempering

The tempering was done in a small kneading machine which had a capacity of about 25#. The moisture content of each mix was determined and enough moisture was added to bring the total water content up to seven percent. After adding the water the mixer was allowed to run five minutes to give equal distribution of the moisture. The mix was then aged for 24 hours to promote a more even distribution of the moisture.

Forming

The test blocks were formed in a hydraulic dry press which was capable of producing a total pressure of 6000 lbs per square inch. The mold box was 20" x 9¼" x

$4\frac{3}{4}$" which makes it possible to form blocks up to a depth of ten inches. By the use of a gauge in the lines between the pump and the compression cylinder it was possible to record the pressure being developed on the blocks at all times during the compression. By the manipulation of the valves it is possible to hold any maximum desired pressure for any length of time. Each block was formed under a constant pressure of 2000# the time of application being regulated with a stop watch.

Drying

The blocks were dryed at room temperature for several days then completely dried at 235 degrees F. Each block being quarted before drying.

Porosity Determined

The apparent porosity was determined by the use of the autoclave. The specimens were immersed in kerosene and a vacuum of $28\frac{1}{2}$" applied for 2 hours. The specimens were then weighed saturated and suspended in kerosene. The apparent porosity being calculated by the following formula - Apparent porosity = Weight saturated - weight dry, divided by, Weight saturated - weight suspended

MATERIALS

The materials used in this research vary greatly in their physical properties, and so cover pratically the entire range of clays used in dry pressing processes.

The following materials and mixes were used:

1. St. Louis Surface Clay(red burning)
2. Cheltengham Clay (fire clay)

TABLE T - 1

Mix: St. Louis Surface Clay 100%
Dry Panned thru 10 Mesh

Forming Pressure 2000#
per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for
Variation of Time of Pressure Application.

Pressure Application / Layer	2sec	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec	10sec
	APPARENT POROSITY IN PER CENT.								
1	27.22	28.05	28.38	27.10	28.00	28.50	28.60	28.50	28.35
2	28.03	28.20	28.60	27.48	28.38	28.60	28.60	28.38	28.50
3	27.75	29.00	29.20	27.80	29.28	28.90	28.93	28.90	29.15
4	28.46	28.80	29.22	28.10	29.40	29.42	29.50	29.45	29.17
5	28.34	29.06	28.82	28.00	29.17	29.10	29.15	29.18	28.85
6	28.32	28.35	28.50	27.98	28.42	28.82	28.85	28.80	28.28
7	27.78	27.50	27.85	27.62	28.20	27.82	27.62	27.90	27.70
8	27.14	27.10	27.50	26.50	27.90	26.72	27.10	27.45	27.15
Average 1-8	27.88	28.50	28.51	27.56	28.59	28.46	28.42	28.52	28.39

PLOT T - 1

VARIATION IN APPARENT POROSITY FOR VARIATION OF
TIME OF APPLIED PRESSURE

PLOT T - 1

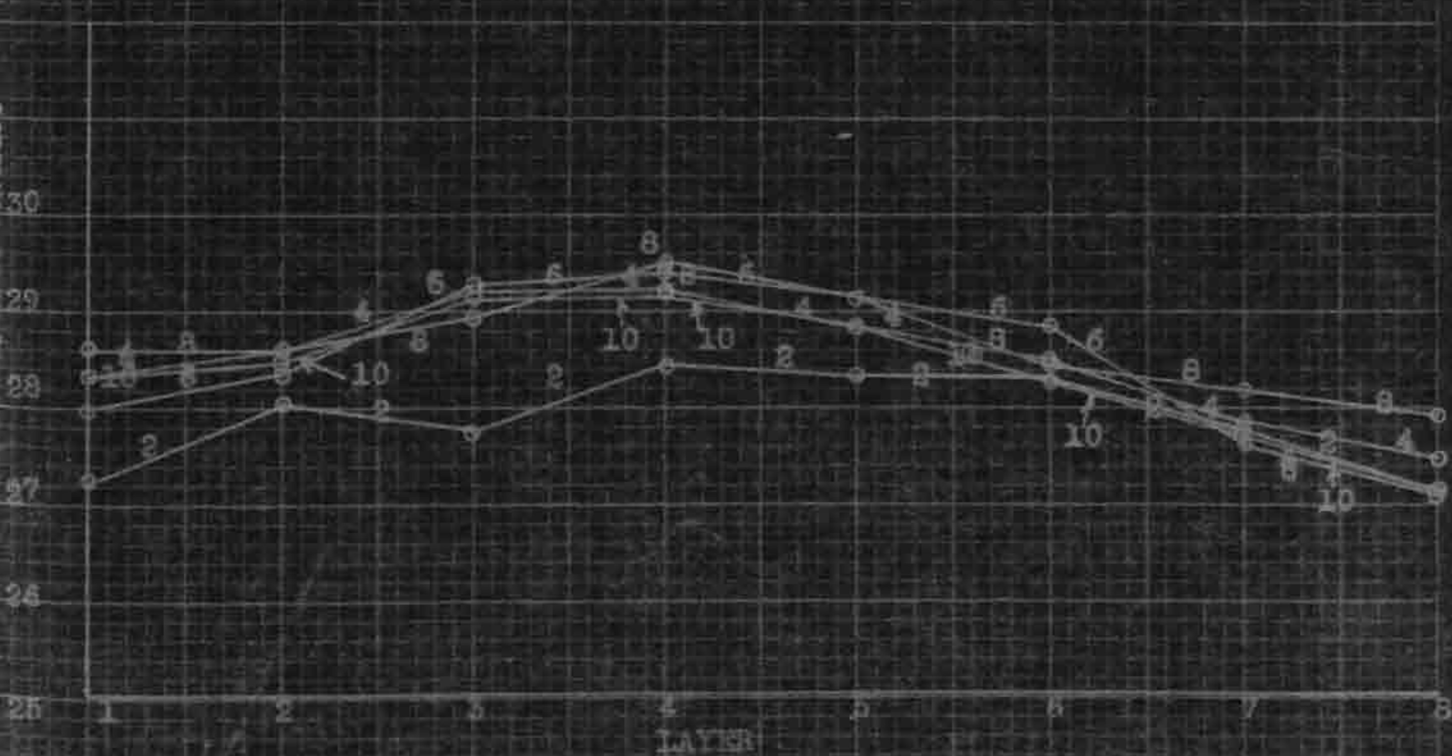


TABLE T - 2

Mix: Cheltenham Clay 100% Dry Panned thru 10 Mesh

Forming Pressure 2000 # per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for Variation of Time of Presure Application.

Pressure Application Layer	2sec.	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec.	10sec
	Apparent Porosity in Per Cent								
1	18.58	18.35	18.15	18.18	18.38	17.85	16.89	18.15	17.99
2	18.15	18.42	18.40	17.85	18.08	17.97	16.85	18.10	17.82
3	17.62	18.85	17.11	17.45	17.80	17.95	17.39	17.70	17.42
4	17.15	17.25	16.83	16.69	17.25	17.50	16.70	16.95	17.42
5	16.98	17.20	16.65	16.65	16.65	16.94	16.60	16.45	16.85
6	16.60	16.50	16.42	16.45	16.35	16.75	16.55	15.90	16.50
7	16.60	16.30	16.40	16.25	15.90	16.45	16.25	15.60	16.30
8	16.25	16.00	16.15	16.00	15.25	16.15	16.10	15.75	15.95
Average 1-8	17.34	17.34	17.01	16.94	16.96	17.19	16.65	16.82	16.99

PLOT T - 2

VARIATION IN APPARENT POROSITY FOR VARIATION OF TIME OF APPLIED PRESSURE

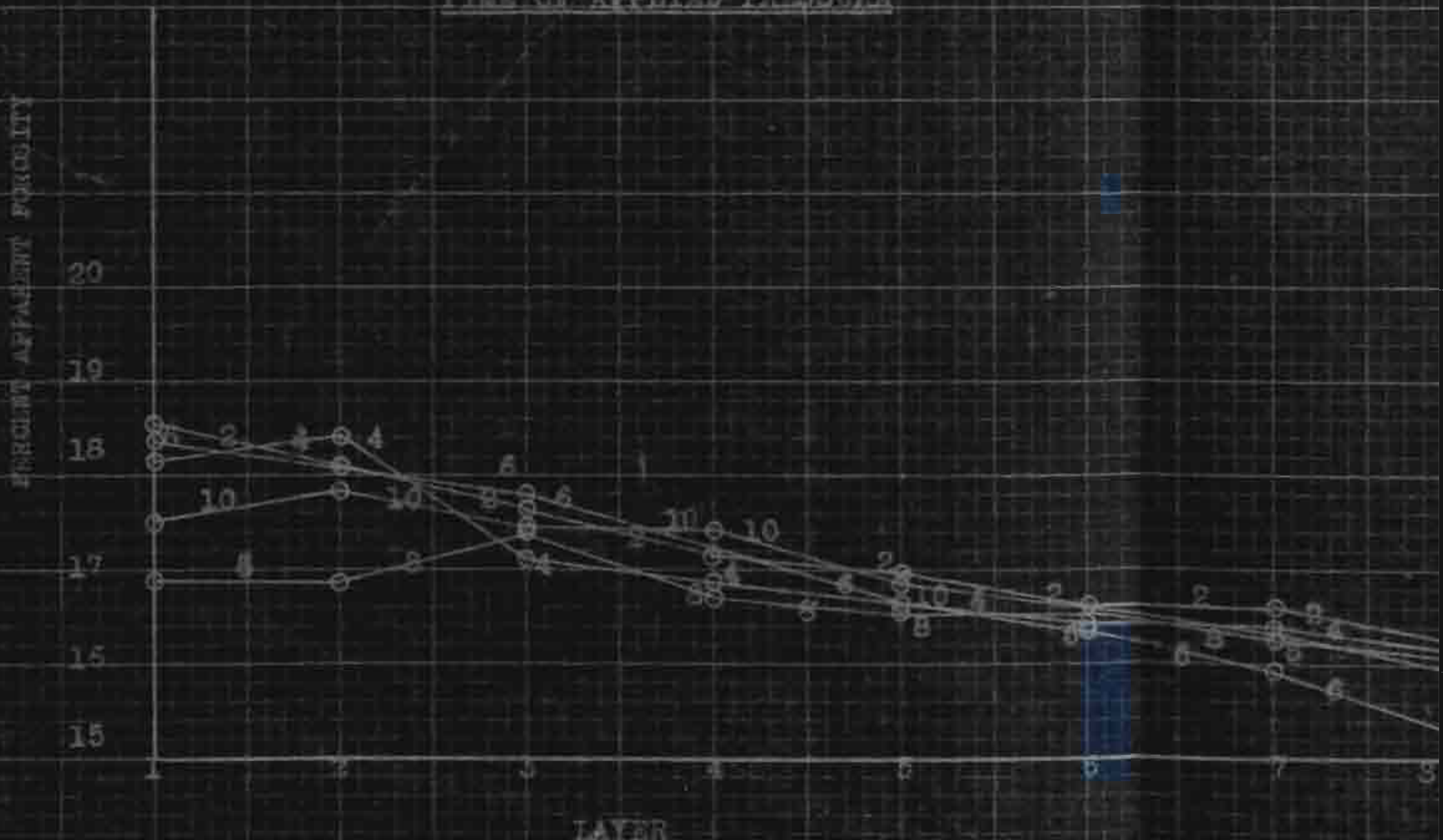


TABLE T - 3

Mix: Cheltenham Clay 85.7%
St. Louis Surface Clay 14.3%
Dry Panned thru 10 Mesh

Forming Pressure 2000# per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for Variation of Time of Pressure Application

Pressure Application	2sec.	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec.	10sec
Layer	Apparent Porosity in Per Cent								
1	18.25	17.60	17.65	18.30	17.88	18.03	18.11	18.15	18.07
2	17.65	17.40	16.65	17.70	17.60	17.78	17.81	18.03	17.79
3	17.35	17.25	15.85	17.60	17.09	17.27	17.48	17.91	16.83
4	17.06	17.10	15.82	17.21	16.92	16.32	18.30	17.30	16.98
5	16.95	16.50	15.60	16.99	16.88	15.32	17.50	17.19	16.93
6	16.70	16.40	15.65	16.96	16.72	15.57	17.55	17.09	16.79
7	16.05	16.30	15.48	16.90	16.65	15.61	17.82	17.00	16.66
8	15.85	15.95	15.46	16.72	16.62	15.99	16.86	16.89	16.49
Average 1-8	16.98	16.81	16.02	17.18	17.04	16.48	17.68	17.43	17.06

PLOT T - 3

VARIATION IN APPARENT POROSITY FOR VARIATION OF TIME OF APPLIED PRESSURE

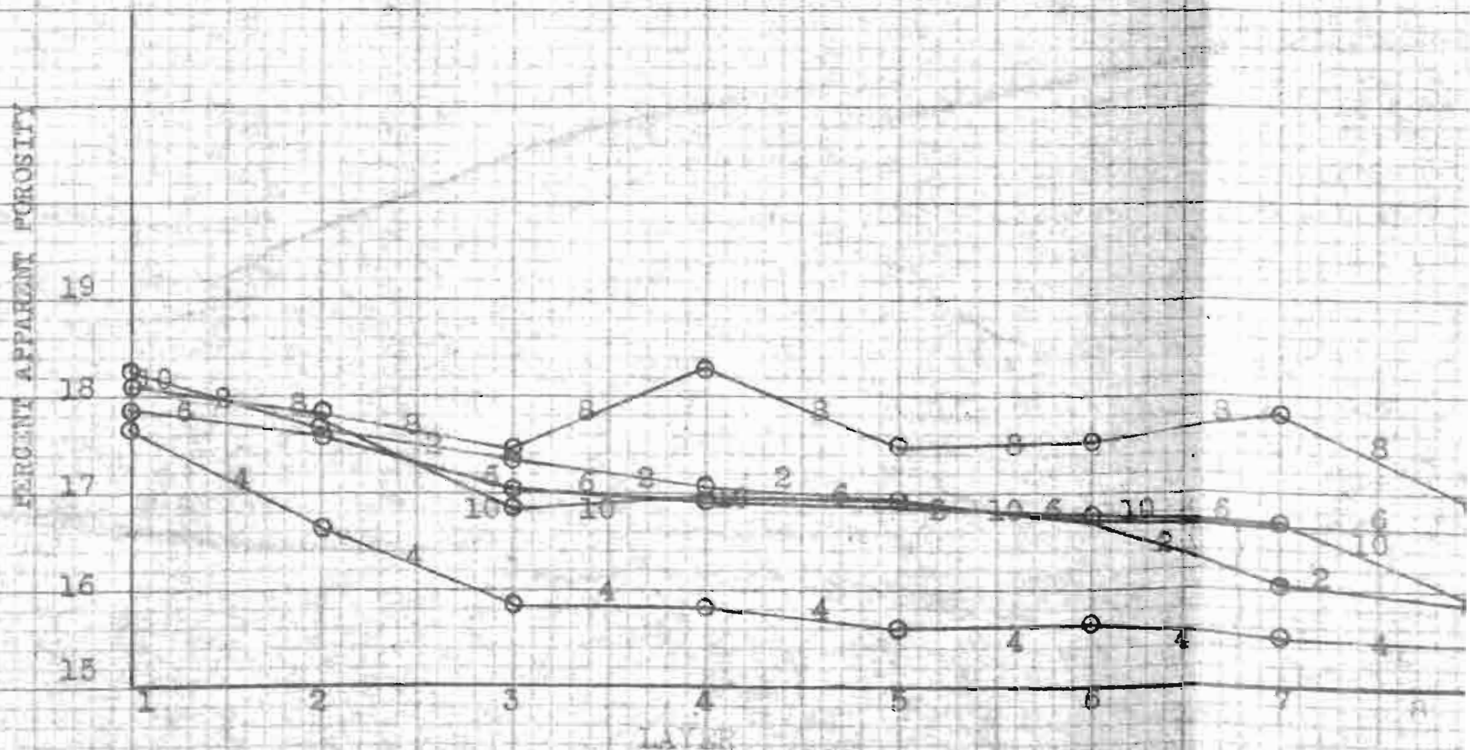


Table T - 4

Mix: Cheltenham Clay 92%
Laclede Christy Grog 8%
Dry Panned thru 8 Mesh

Forming Pressure 2000# per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for Variation of Time of Pressure Application

	Pressure Application								
	2sec.	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec.	10sec.
Layer	Apparent Porosity in Per Cent								
1	20.50	20.96	21.00	22.48	19.48	19.45	18.37	18.20	18.57
2	20.68	20.62	20.82	22.45	19.70	19.50	18.12	18.60	18.35
3	20.70	20.19	19.90	21.22	19.90	19.81	18.05	18.27	19.41
4	20.23	19.88	19.82	21.03	20.03	19.49	17.94	18.12	18.65
5	20.02	19.51	19.75	20.25	20.21	19.46	17.85	17.82	18.40
6	19.75	19.33	19.39	20.13	19.76	19.42	17.56	17.68	18.22
7	19.64	19.15	18.70	19.83	19.65	19.34	17.42	17.60	18.07
8	19.35	19.00	18.56	19.28	19.63	19.20	17.32	17.52	18.01
Average 1-8	19.92	19.82	19.76	20.33	19.98	19.46	17.94	17.97	18.46

PLOT T - 4

VARIATION IN APPARENT POROSITY FOR VARIATION OF TIME OF APPLIED PRESSURE

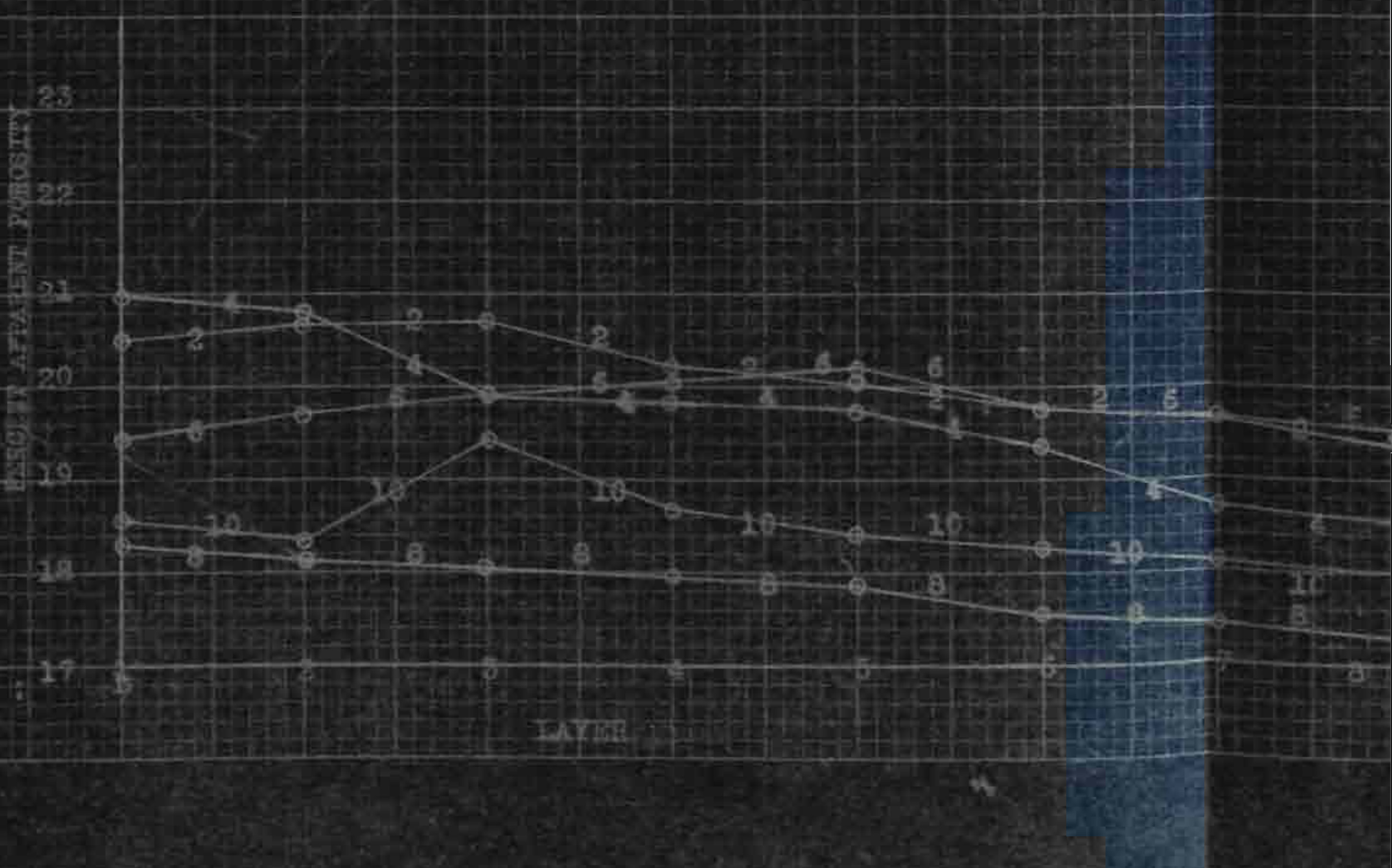


Table T - 5

Mix: North Mo. Semi-Flint 92% & Grog 8% thru 8 Mesh

Forming Pressure 2000# per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for Variation of Time of Pressure Application

Pressure Application Layer	2sec.	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec.	10sec
	Apparent Porosity in Per Cent								
1	19.80	20.60	21.20	19.75	20.20	20.17	19.33	19.47	20.65
2	20.35	20.71	21.43	20.25	20.10	20.34	19.56	19.12	19.89
3	20.21	20.60	21.03	20.30	19.68	20.35	19.82	18.92	20.63
4	20.11	20.21	20.75	19.83	19.50	19.94	18.69	18.90	19.99
5	19.94	20.10	20.55	19.69	19.30	19.86	18.34	18.13	19.76
6	19.83	19.65	19.84	19.26	18.75	19.26	17.86	18.11	19.16
7	19.72	18.73	19.35	19.42	18.71	18.80	17.79	17.83	18.76
8	18.62	18.45	18.80	18.64	18.54	18.50	17.08	17.75	18.34
Average 1-8	19.76	19.88	20.37	19.64	19.35	19.65	18.58	18.53	19.67

PLOT T - 5

VARIATION IN APPARENT POROSITY FOR VARIATION OF TIME OF APPLIED PRESSURE

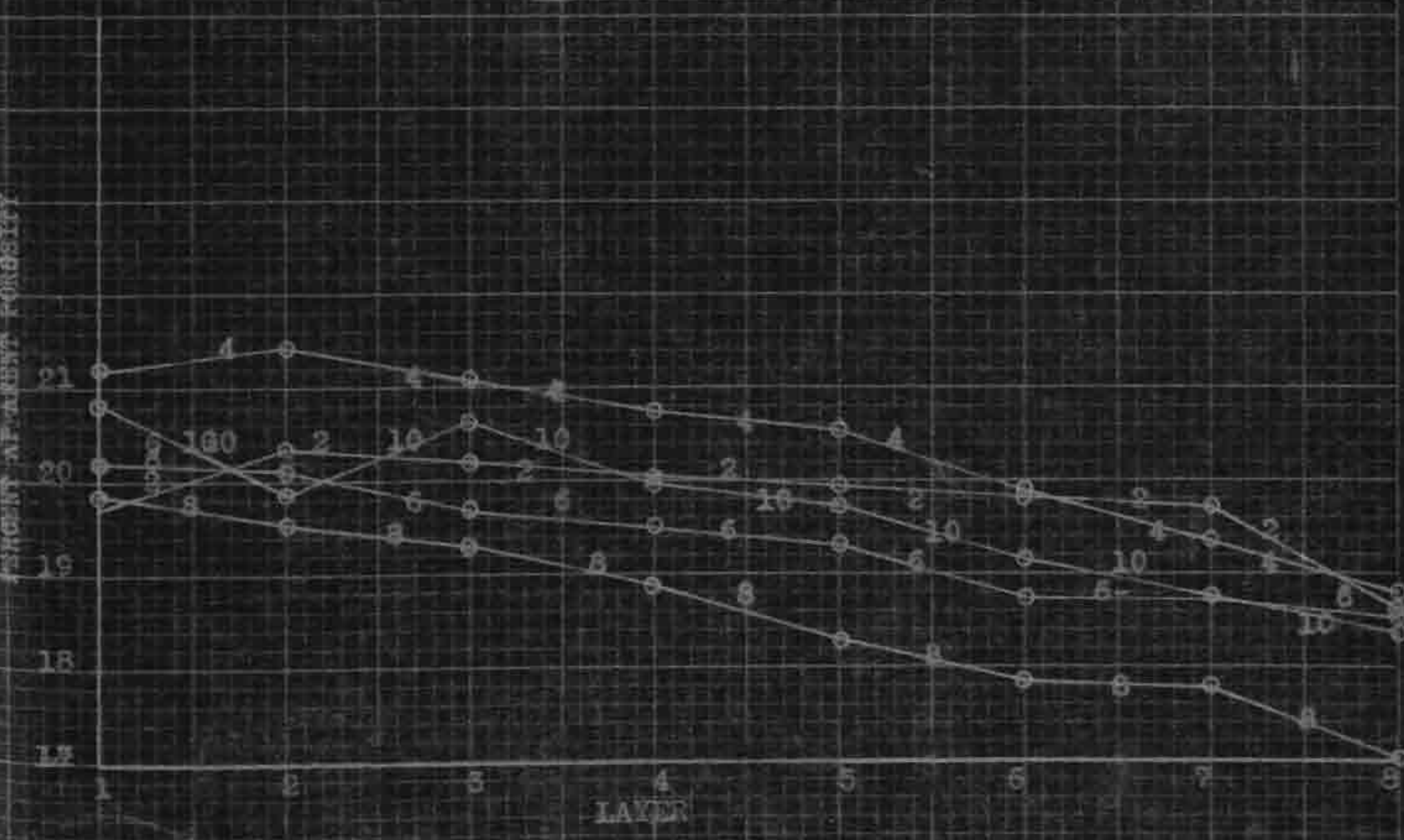


Table T - 6

Mix: Mo. No 1 Flint Clay 75%
Cheltenham Clay 25%
Dry Panned thru 8 Mesh

Forming Pressure 2000# per. sq. in. 7% Moisture

Vertical Variation in Apparent Porosity for Variation of Time of Pressure Application.

Pressure Application	2sec.	3sec.	4sec.	5sec.	6sec.	7sec.	8sec.	9sec.	10sec.
Layer	Apparent Porosity in Per Cent								
1	26.80	27.00	26.85	25.50	26.80	26.80	26.80	26.00	26.00
2	27.82	27.60	26.90	27.10	27.10	26.55	26.70	26.90	26.70
3	27.80	27.30	27.00	27.50	27.30	27.30	26.90	26.85	27.05
4	27.50	27.30	27.20	27.20	27.10	26.90	26.80	27.30	27.15
5	27.18	27.20	26.60	26.80	26.10	27.40	26.80	26.95	26.75
6	26.78	26.30	26.20	26.40	26.00	27.00	25.85	26.70	26.25
7	26.30	26.10	25.60	25.70	25.90	26.50	25.40	25.75	25.70
8	25.82	25.30	25.20	25.45	25.83	25.70	25.20	25.60	25.35
Average 1-8	27.00	26.76	26.44	26.45	26.51	26.68	26.28	26.50	26.37

PLOT T - 6

VARIATION IN APPARENT POROSITY FOR VARIATION OF TIME OF APPLIED PRESSURE

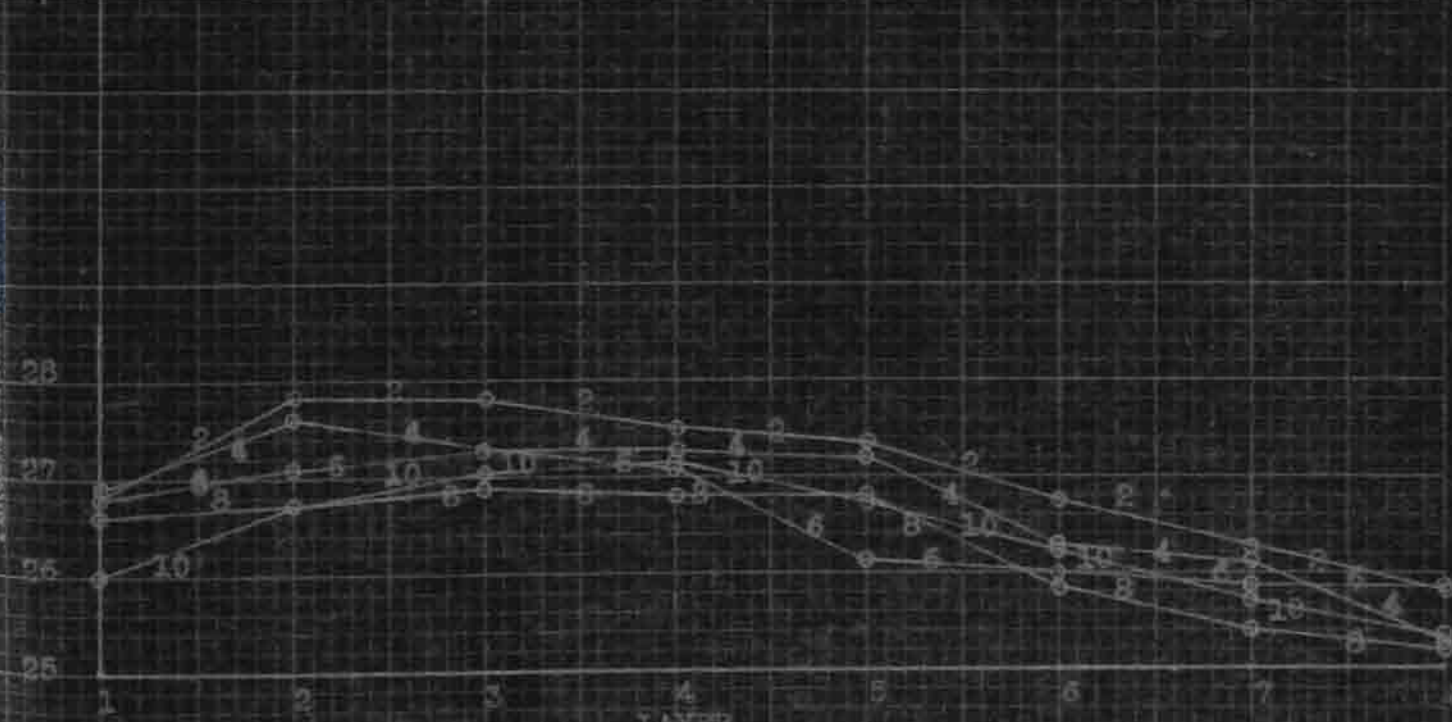


TABLE T_{ap}

VARIATION IN APPARENT POROSITY FOR VARIATION IN TIME OF APPLIED PRESSURE

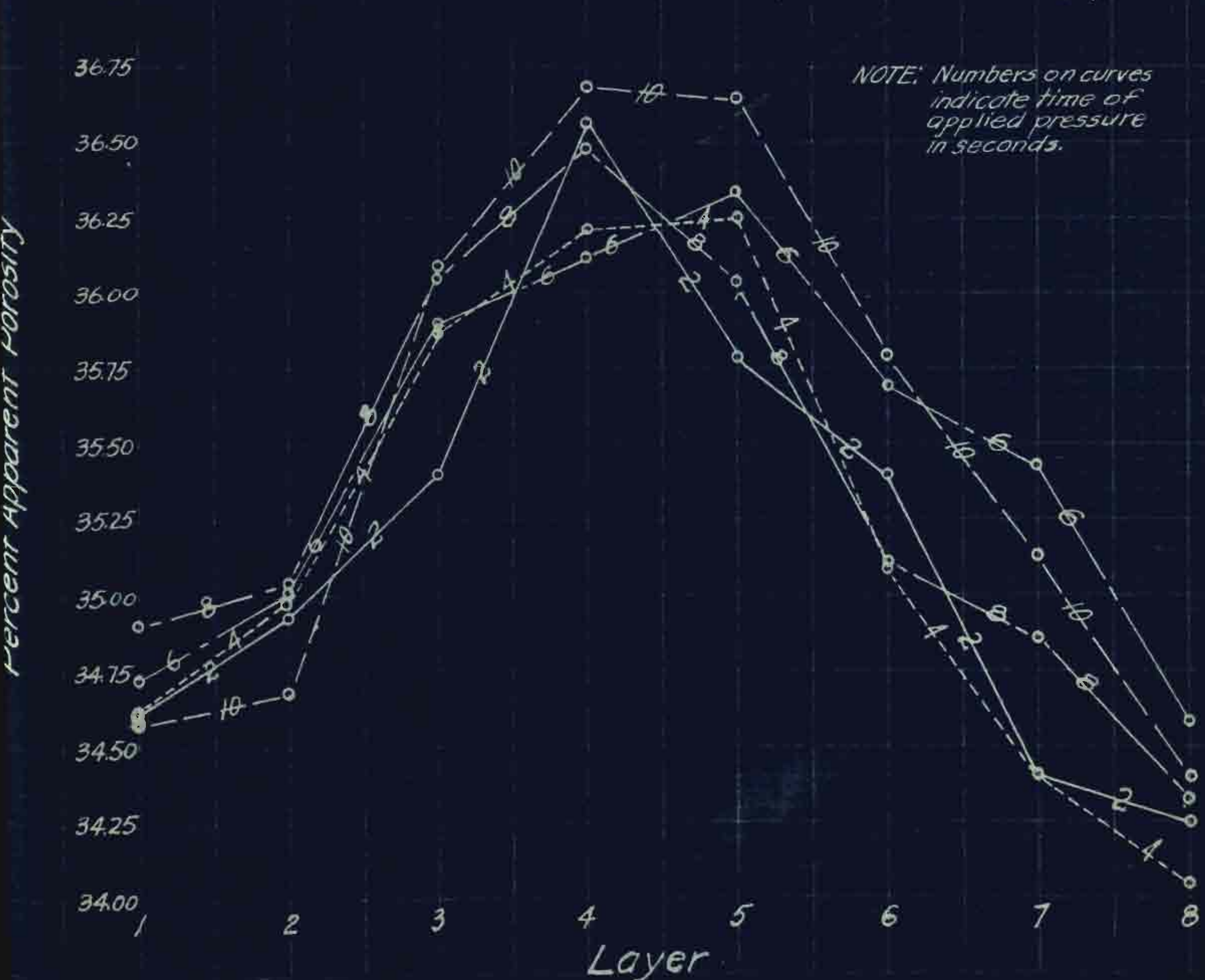
St. Louis Surface Clay 100% - Dry Panned thru 10 Mesh - Moisture 8% -
Applied Pressure 500 lbs. per sq. in.

Layer	APPARENT POROSITY IN PERCENT				
	2 seconds Application	4 seconds Application	6 seconds Application	8 seconds Application	10 seconds Application
1	34.62	34.63	34.73	34.86	34.58
2	34.93	34.99	35.01	35.05	34.68
3	35.40	35.87	35.90	36.05	36.08
4	36.59	36.21	36.12	36.48	36.68
5	35.78	36.25	36.34	36.04	36.65
6	35.40	35.08	35.69	35.11	35.79
7	34.41	34.40	35.43	34.86	35.13
8	34.25	34.05	34.58	34.33	34.40

PLOT T_{ap}

Variation in Apparent Porosity for Variation of Time of Applied Pressure

St Louis Surface Clay - Dry Panned thru 10 Mesh - Moisture Addition 8%
Applied Pressure 500 lbs/sq.in.



3. Cheltengham Clay 35.7% - St. Louis Surface Clay 14.3%
4. Cheltengham Clay 92% - Fire Brick Grog 8% - L.
5. North Missouri Semi-flint Clay 92% - Fire Grog 8%.
6. Missouri No 1 Clay 75% - Cheltengham Clay 25%.

These materials are representive of the important materials used in making building and fire brick.

DISCUSSION OF DATA

In all cases, the porosity curves were ploted, with the abscissae representing the position of the various layers and the ordinates the percent apparent porosity. The layers being numbered 1-8 from top to bottom respectively. On each curve the number is printed showing the time of pressure application. Due to the small variation in apparent porosity for the various periods of pressure dwell, only the curve for every other block was plotted, that is data for 2,4,6,8 and 10 seconds time of applied pressure were plotted, to make it easier to distinguish the various curves. The data corresponding to each plot are located just above each plot on the same page. The mix for each set of data and curves is given at the top of the corresponding page.

Table T - 1 and Plot T - 1, show the data obtained on St. Louis Surface Clay, which has been dry panned to pass a ten mesh, tempered with 7 percent moisture and formed at 2000 lbs per square inch pressure. It will be noticed that while the curves for this clay indicate that the porosity decreases as the top and bottom of the block are approached, this characteristic is not materially changed as the time of pressure application is varied from two to ten seconds. The curve shown for 2 seconds application indicates a lower porosity in the upper layers of the block than do the longer pressure duration curves, but the general shape of the curve follows that of the 4.6,8 and 10 second curves. This indicates that within the limits of form 2 to 10 seconds variation in time of applied pressure has little or no effect on presure transmission.

The soft center indicates by the higher porosity in the central layers of the block may be attributed to the characteristics of this particular clay, which is a loess, containing a high percentage of fine grained silica.

There are three possible theories which may be advanced as an explanation for its lack of pressure transmission properties. (1) That a solid which does not deform would transmitt applied pressure perfectly from one end to the other. As this solid is cut up or divided into finer and finer particles the number of particle contacts is increased. Each contact which must be made is a possible source of pressure dissipation. Manifestly the greater the number of contacts the poorer the pressure transmission due to small grains. (2) The fewer the number of contacts that a clay makes with the mold-box linning the less friction there is developed.

Accumulated friction from the point of pressure application to the center of the block may account for the high porosity in the fourth layer from the top. (3) Fine grained clay would have small interstatial pores. The application of pressure would have a tendency to close these pores still more, thus cutting off the avenue of escape for any air contained in the interatatial pores in the interior of the block. When pressure is applied the air would compress and again expand upon release of the pressure, causing a relatively high porosity through out that portion of the block which it occupies.

Table T 2 and Plot T 2 represent the data on Cheltenghan clay dry panned through 10 mesh, tempered with 7 percent moisture and formed under a pressure of 2000 lbs per square inch. This data shows by the small variation in porosity from top to bottom of the block that this clay has exceptionally good pressure trans - mission characteristics, which may be due in part to its high plasticity, which would allow one grain to slip easily over another grain thus reducing internal friction and aiding pressure distribution. The various curves almost coeinside which again indicates that ten seconds time of applied pressure shows no advantage over an in- terval of two seconds.

Table T 3 and Plot T 3 where 85.7 per cent Cheltenghan and 14.3 per cent St. Louis surface clay formed under the same conditions as for the two previous mixes, indicates the same conditions as that found in the Cheltngham clay alone. Although two of the curves namely, 3 seconds, and 4 seconds, have a little higher and a little lower total porosity than the other curves, their slope is substantially the same, thus indicating similar pressure transmission characteristics.

Table T 4 and Plot T 4, and Table 5 and Plot 5 represent Cheltengham clay 92 per ecnt, Laclede King Grog 8 per eent and North Missouri semi flint clay 92 per cent and Green Empire Grog 8 per cent, respectively. It is note worthy that these two mixes have about the same apparent porosity and show fairly good pressure transmission properties at 2000 lbs per square inch pressure through out the whole range of time intervals. While the curves for these two mixes are more widely seperated than these of the previous mixes there is a similarity of slope for all curves which would show that time of pressure application has little or no effect on the uniformity of pressure transmission.

Table T 6 and Plot T 6 show that the pressure transmission characteristics of Missouri Number one Flint clay 75 per cent and Cheltengham clay 25 per cent are similar to those of the surface clay, that is, there is a higher porosity at the center of the block, indicating a softer center than is found in any of the other mixes with the exception of these two. The curves for the various time intervals however are almost parell and so have the same conclusion as regards time of application as stated above, may be drawn.

Table Tap and Plot Tap in which St. Louis Surface clay dry panned thru 10 mesh and tempered with 7 per cent moisture, formed at 500 lbs per square inch, was run as a check, to accentuate the difference in porosity also indicates that time of applied pressure has no effect on pressure transmission.

CONCLUSIONS AND SUMMARY

The following conclusions as sumerized might be stated, of course taking into consideration the conditions of these experiments, and those which would prevail in the application of these results to commercial processes.

1. Finely ground non-plastic materials are not conductive to pressure transmission.
2. The characteristics of the Cheltengham clay seem to be more suitable for better transmission of pressure than the other clays studied.
3. A small amount of grog seems to promote the transmission of pressure and thus lowers theporosity for a given pressure and time of application.
4. The variation of the length of time of pressure application has very little effect upon the vertical transmission of pressure. Altho there is probably a lower limit which must be less than the 3 seconds dwell now employed on commercial dry presses.
5. The rate of pressure application is perhaps the most important time consideration in obtaining better pressure transmission in dry pressing.

RECOMMENDATIONS FOR FURTHER RESEARCH

It would be desirable to repeat the foregoing test with less time of pressure application, also with a variation in the degree of pressure used. The rate of pressure application would be a factor worth considering along with the above mentioned factors.

A combination can possibly be reached which would give minimum porosity with minimum time application and degree of pressure.

It would also be desirable to determine the percentage of plastic and non-plastic materials which would give the greatest degree of pressure transmission through out the blocks.

ACKNOWLEDGEMENT

The writer wishes to acknowledge the kind assistance and practical advice given to him by Mr. Paul and Prof. C. M. Dodd.

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