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The transmission of pressure in the dry pressing of typical building brick and fire brick mixes as affected by the degree of pressure, physical character of mix ingredient, and the moisture content of the mix

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THE TRANSMISSION OF PRESSURE IN THE DRY PRESSING OF TYPICAL BUILDING BRICK AND FIRE BRICK MIXES AS AFFECTED BY THE DEGREE OF PRESSURE, PHYSICAL CHARACTER OF MIX INGREDIENT, AND THE MOISTURE CONTENT OF THE MIX

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THESIS

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PART II

INTRODUCTION

In February, 1929, the Dry Press Committee of the National Brick Manufacturers Association, in cooperation with the department of Ceramics of the Missouri School of Mines and Metallurgy, began several investigations relating to dry press ware. This Committee suggested a great number of possible investigations, and are now systematically proceeding along these lines.

This investigation has for its object:

(1) The transmission of pressure in the dry pressing of typical building brick and fire brick mixes as affected by the degree of pressure; and

(2) As affected by the moisture content of the mix.

This thesis contains a description of equipment and raw materials used, and a detail of the testing methods.

REASONS FOR INVESTIGATION

It has long been the object of refractories companies to be able to make a dry press block of depths greater than four or six inches. To date, several companies have successfully made blocks of six inch depth and eighteen to twenty-four inch lengths by increasing the time of the application of pressure, but due to the various physical properties of the mixes and the means of applying the pressure, most of the attempts to increase the depth of the ware produced has resulted in too great a loss.

Certain properties of dry press ware can be controlled in the composition of the mix and in the firing of the ware, but many defects develop when a body is made of greater depths than four inches. Laminations, soft centers, and air cracks,all due to entrapped air, are the result of increasing the size of the ware. This is due to the unequal compression in various parts of the ware. While a fluid transmits pressure equally in all directions, the same is not true of a clay body, as the pressure must be transmitted from grain to grain. Due to the difference in grain size, friction between the grains, and poor lubrication of the grains, the external pressure applied to the body is not distributed equally thruout the mix.

Undoubtedly this transmission of pressure will be affected by the shape of grain, size of grain, percentage of fines and course grains, plasticity of the mix, moisture content of mix, occluded air, degree of pressure, and time and rate of application of the pressure.

MATERIALS USED

The materials that were used in this investigation cover practically all of the general types of clays used in dry press bodies. These materials, with their percentages and mixes are as follows:

1. St. Louis Surface Clay (red burning loess) 100%

2. Cheltenham Clay.......... 85.7%
   St. Louis Surface Clay... 14.3%

3. Cheltenham Clay 92%
   Fire Brick Grog..... 8%

4. North Missouri Semi-flint Clay 92%
   Fire Brick Grog................ 8%

5. Missouri No. 1 Flint Clay...... 75%
   Cheltenham Clay................ 25%

6. Progress Press Brick Clay 100%

EQUIPMENT FOR MILLING

In preparing the mixes used for the dry press ware, the Cheltenham clay and the grog were first passed thru the jaw crusher and reduced to 3/8 inch size. These were then proportioned among the various mixes in which they were used and then dry panned. The building brick mixes were screened thru 10 mesh and the fire brick mixes thru 8 mesh in a Great Western Manufacturing Company Gyratory Riddle.

The entire batch was quartered down to a suitable sample for screen analysis. Those samples were placed in a Tyler Rotap machine for twenty minute periods. The contents of each screen was weighed to the nearest hundredth of a gram and the percentage determined. These results are as follows:

TABLE I

SCREEN ANALYSIS OF DRY PANNED MIXES

Tylor Standard Sieve	#1	#2	#3	#4	#5
On 8	0.00%	0.00%	0.00%	0.00%	0.00%
Thru 8 on 10	0.00%	0.00%	6.61%	10.73%	13.40%
Thru 10 " 14	11.33%	17.37%	14.80%	11.58%	13.04%
Thru 14 " 20	8.87%	9.59%	11.49%	9.04%	10.10%
Thru 20 " 28	10.48%	10.80%	13.80%	11.87%	12.40%
Thru 28 " 35	7.32%	7.61%	9.77%	8.90%	9.61%
Thru 35 " 48	5.40%	5.91%	8.02%	7.40%	8.43%
Thru 48 " 65	3.84%	4.94%	6.75%	6.61%	8.37%
Thru 65 " 100	3.39%	6.48%	9.96%	10.42%	9.85%
Thru 100 " 150	2.37%	8.59%	6.94%	8.13%	7.21%
Thru 150 " 200	1.04%	3.84%	2.80%	3.42%	2.20%
Thru 200	46.00%	24.53%	9.89%	12.05%	5.30%
Total	100.04%	100.02%	100.01%	100.03%	99.98%

TEMPERING

The tempering of these various mixes was done in a small kneading machine. The amount of moisture originally present in the clay was determined by taking a known amount of mix, usually 300 grams, drying at 110°C. for 24 hours, cooling in a desiccator to room temperature and again weighing. This moisture was then subtracted from the amount necessary to give a 7% moisture content to the batch. The water was added by hand and the batch kneaded in the machine for ten minutes. It was then allowed to age for twenty-four hours, to give an even distribution of the water to the mix, before being formed in the dry press.

FORMING

The blocks were formed in a Hydraulic Press Manufacturing Company hydraulic press capable of giving a maximum pressure of about 6000 lbs. per sq. in. or 135 tons on a 9-3/4" x 4-3/4" brick. The mold box of this press was 9-3/4" x 4-3/4" and twenty-two inches deep, thus making it possible to form blocks of ten inch depths. The lower ram was able to move thru a distance of 22 inches while the upper ram moved 1-3/4 inches. Though the rate of movement of the rams was slower than those of a mechanical press, yet this was the only type in which the applied pressure could be measured at all times during the operation. A gauge was installed in the line between the press and the electric pump to indicate this pressure. A valve on the pump allowed a variation in maximum pressure at any one time.

Approximately 36 lbs. of mix were made for each test and this was introduced in weighed amounts, capable of filling a mold 2 inches deep. Eight of these batches were added to form the block and then the pressure applied, the maximum pressure being held for 2 seconds. It took an average of 15 seconds to obtain the maximum pressure.

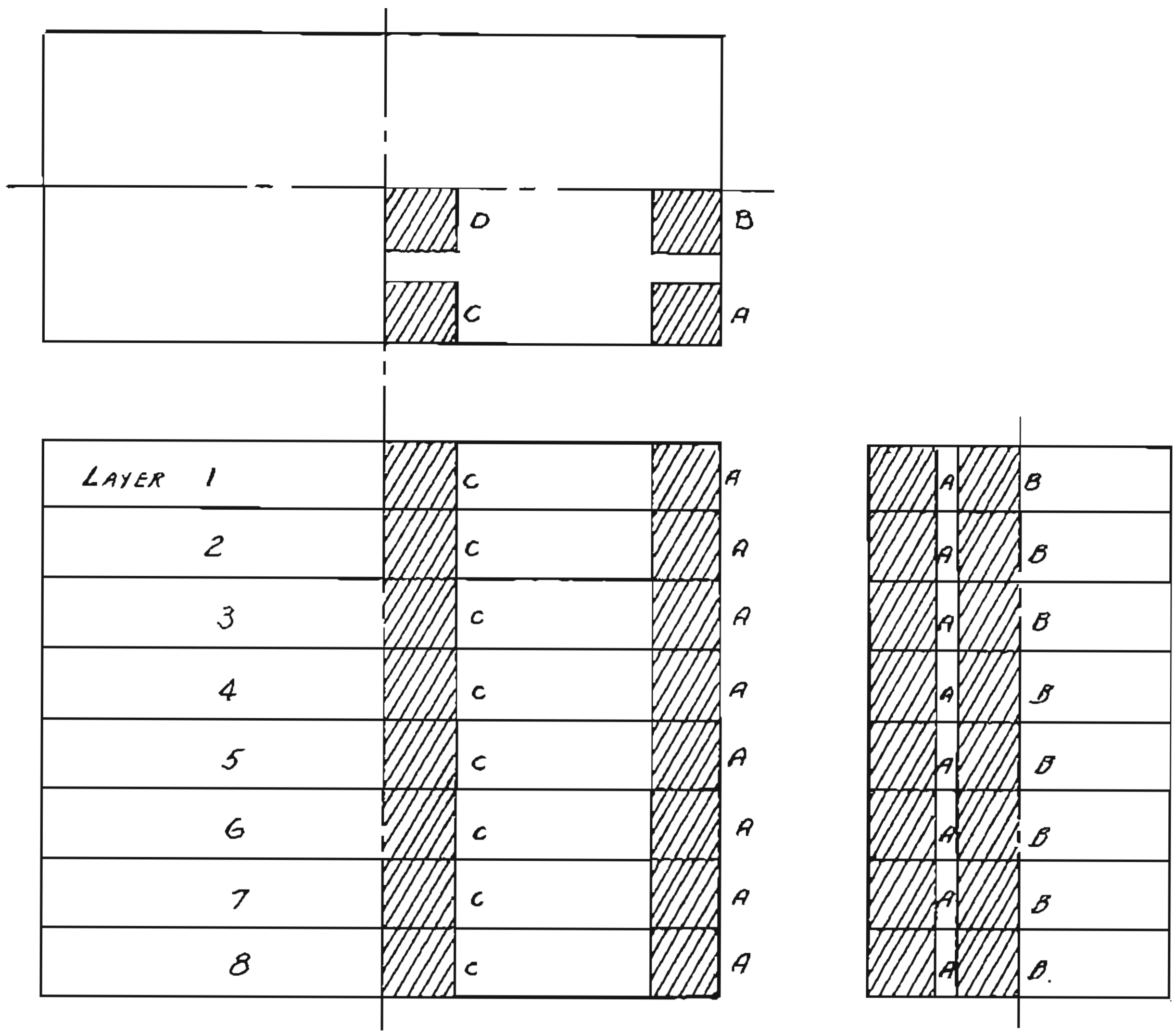
DRYING

After being formed, the blocks were allowed to dry for 5 days at room temperature, then they were cut up to the desired size specimens and dried at 235°F.

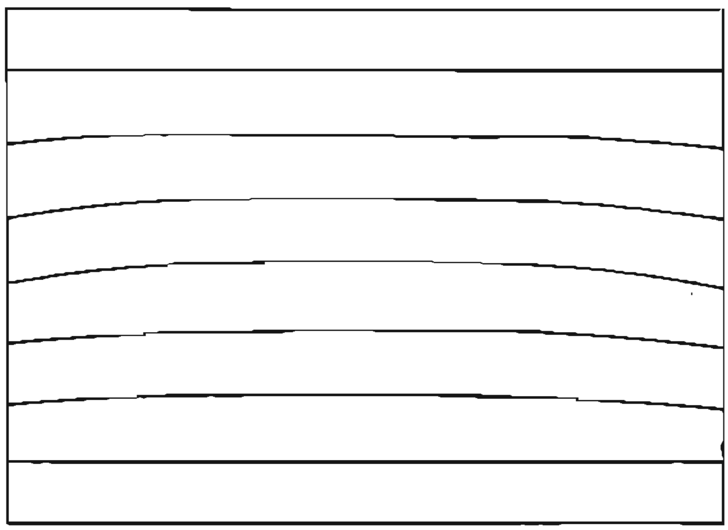
TESTS MADE

Most of the tests were made according to the standard procedure of the American Ceramic Society and of the American Society for Testing Materials, with however, some changes made necessary by local conditions. The principal change was the determination of the pressures developed at the various levels of the block. Many ideas were carefully considered, among them being the determination of the density of the various levels by means of the Vicat needle. By measuring the amount of penetration of this needle, it was hoped that a relation could be worked out with a standard 2" block and the test block and conclusions be drawn from it. This had to be discarded as several of the bodies contained grog, which would seriously retard the amount of penetration of the needle should it strike the grog. Other suggestions were, placing horizontal plungers at the different levels of the block, and connecting these to pressure gauges, copper tubes placed at the different levels and measuring the collapse of these tubes, placing carbon plates at various levels and measuring the amount of current flowing thru them. All these were discarded due to mechanical complications, no standards of comparison and also the time necessary to construct and install all these parts.

It was finally decided to determine the bulk specific gravity and the apparent porosity of specimens taken from the different levels. These specimens were taken from the block as shown in the figure below:



In order to obtain these samples it was necessary to devise a means of splitting the block at regular intervals and obtain the desired size sample. This was accomplished by introducing a thin layer of finely ground flint between each level. A definite amount of clay by weight, 4½ lbs., was introduced to the mold box and a thin layer of flint sprinkled over each layer. After the block was formed it was an easy matter to break it up into its separate layers, as the flint had no bonding power. The flint also showed the flow of the clay in each layer. This flow was down in the corners and up in the center, thus forming a convex layer. This is illustrated in the following figure:



Eight layers composed each block and each layer was 2 inches deep before the pressure was applied. By adding a definite amount of clay by weight, more accurate sized layers were obtained.

The bulk specific gravity and apparent porosity of each specimen was determined from the following formulae:

$$\text{Bulk Specific Gravity} = \frac{\text{Weight Dry}}{\dfrac{\text{Weight Saturated} - \text{Weight Suspended}}{\text{Sp.Gr. of Kerosene}}}$$

$$\text{Apparent Porosity} = \frac{\text{Weight Saturated} - \text{Weight Dry}}{\text{Weight Saturated} - \text{Weight Suspended}}$$

The specimens were first dried and weighed and then saturated in kerosene under a vacuum of 26 inches of mercury for 3 hours. The saturated and suspended weights were then determined.

DATA

On the following pages are the data and curves obtained.

In the first table is the bulk specific gravity and apparent porosity of Mix No. 1, namely 100% St. Louis Surface Clay, and is used in making building brick.

In Table B is given the data on Mix No. 2 consisting of 85.7% Cheltenham Clay and 14.3% St. Louis Surface Clay, all dry panned thru 10 mesh. The mix is commonly used for making building brick.

Table C gives the data on Mix No. 3 consisting of 92% Cheltenham Clay and 8% Grog, and is used for fire brick mixes.

Table D gives the data on Mix No. 4 consisting of 92% North Missouri Semi-Flint Clay and 8% Grog and is used in making fire brick.

Table E gives the data on Mix No. 5 consisting of 25% Cheltenham Clay and 75% Missouri Flint Clay.

TABLE - A

Mix:
St. Louis Surface Clay - Ground in Dry Pan Through 10 Mesh.

VERTICAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURE IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
1	1.705	35.44	1.755	33.48	1.745	33.80	1.748	34.05	1.760	32.92	1.790	31.71
2	1.680	36.26	1.740	34.07	1.730	34.64	1.770	32.23	1.765	32.68	1.800	31.25
3	1.655	37.21	1.720	34.85	1.728	34.67	1.755	32.27	1.780	31.95	1.815	31.03
4	1.636	37.89	1.700	35.66	1.733	34.59	1.778	32.87	1.818	31.55	1.830	29.29
5	1.660	37.08	1.710	35.07	1.753	33.72	1.790	32.46	1.820	30.36	1.858	29.01
6	1.660	36.80	1.728	34.35	1.783	32.51	1.818	31.35	1.843	29.68	1.870	28.20
7	1.720	35.64	1.748	33.43	1.790	32.41	1.813	31.49	1.860	28.97	1.905	27.02
8	1.720	33.17	1.770	32.81	1.813	31.53	1.835	30.61	1.883	27.68	1.923	26.45
Avg. 1-8	1.679	36.19	1.734	34.21	1.759	33.48	1.786	32.17	1.816	30.72	1.849	29.42
Depth of Finished Block	9.06"		8.90"		8.86"		8.66"		8.64"		8.24"	

TABLE A-1

Mix:
Same as given in Table A.

HORIZONTAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURES IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
Block	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
A	1.680	35.90	1.739	34.01	1.766	33.20	1.788	32.18	1.824	30.37	1.853	29.48
B	1.676	36.10	1.734	34.15	1.759	33.60	1.794	31.99	1.814	30.66	1.851	29.45
C	1.678	36.20	1.736	34.14	1.758	33.53	1.784	32.13	1.815	30.71	1.834	29.00
D	1.680	36.55	1.730	34.38	1.754	33.73	1.789	32.35	1.811	31.15	1.839	29.68
Avg. A-D	1.679	36.19	1.735	34.17	1.759	33.52	1.789	32.16	1.816	30.72	1.849	29.42
Block Thickness	9.06"		8.90"		8.88"		8.60"		8.64"		8.24"	

TABLE B

Mix:
Cheltenham Clay 85.7%
St. Louis Surface Clay 14.3%
) Ground in Dry Pan - Through 10 Mesh.

VERTICAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURE IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
1	1.918	26.75	1.925	27.02	1.930	26.13	1.995	23.61	2.015	23.21	2.070	20.66
2	1.893	27.91	1.888	28.72	1.953	26.08	1.955	23.13	2.018	22.67	2.080	19.95
3	1.860	29.40	1.895	28.22	1.965	25.50	2.038	22.38	2.055	21.20	2.130	16.51
4	1.873	28.98	1.930	28.25	2.010	24.01	2.063	20.88	2.093	19.60	2.153	17.43
5	1.900	27.64	1.943	26.28	2.045	22.40	2.078	19.88	2.065	18.31	2.178	16.15
6	1.940	26.41	1.985	24.62	2.065	21.14	2.128	18.43	2.160	17.39	2.195	15.60
7	1.973	25.10	2.013	23.31	2.105	20.04	2.148	17.56	2.175	16.61	2.208	15.21
8	2.015	23.54	2.048	21.83	2.125	19.11	2.128	16.90	2.190	16.00	2.210	15.07
Avg. 1-8	1.922	26.97	1.953	26.03	2.029	23.05	2.065	20.37	2.099	19.40	2.154	17.32
Depth of Finished Block	10.38"		10.25"		9.86"		9.46"		9.64"		9.50"	

TABLE B-1

Mix:
Same as given in Table B.

HORIZONTAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

Location	FORMING PRESSURES IN LBS. PER SQ. IN.											
	500		1000		1500		2000		3000		4000	
Block	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
A	1.925	27.00	1.965	26.01	2.033	22.81	2.076	20.42	2.098	19.64	2.146	17.55
B	1.928	26.67	1.955	25.80	2.021	22.99	2.071	20.28	2.110	19.32	2.154	17.16
C	1.925	26.66	1.951	25.89	2.039	22.81	2.080	20.42	2.098	19.12	2.159	17.52
D	1.908	27.33	1.944	26.43	2.021	23.58	2.031	20.37	2.098	19.51	2.156	17.36
Avg. A-D	1.922	26.97	1.953	26.03	2.029	23.05	2.065	20.37	2.099	19.40	2.154	17.35
Block Thickness	10.38"		10.36"		9.98"		9.46"		9.64"		9.56"	

TABLE C

Mix:
Cheltenham Clay 92%) Ground in Dry Pan - Through 8 Mesh.
Fire Brick Grog 8%)

VERTICAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

Location	FORMING PRESSURE IN LBS. PER SQ. IN. 500		1000		1500		2000		3000		4000	
	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
1	2.046	21.96	2.100	21.07	2.105	20.29	2.115	19.47	2.170	18.50	2.180	18.52
2	2.045	22.20	2.073	20.16	2.102	20.10	2.128	19.71	2.185	18.63	2.150	18.06
3	2.012	23.03	2.075	21.16	2.100	20.34	2.085	19.46	2.183	18.43	2.160	18.51
4	2.020	22.80	2.090	20.51	2.112	20.14	2.128	19.72	2.185	18.30	2.170	18.26
5	2.030	22.94	2.095	20.13	2.105	19.58	2.130	19.44	2.175	17.89	2.180	17.81
6	2.030	23.00	2.083	21.25	2.125	19.36	2.133	19.18	2.170	17.92	2.180	17.84
7	2.056	22.07	2.097	20.18	2.125	19.59	2.145	19.01	2.183	17.41	2.190	17.58
8	2.035	21.91	2.125	19.54	2.127	19.23	2.140	18.80	2.183	17.22	2.180	17.58
Avg. 1-8	2.034	22.49	2.092	20.50	2.113	19.80	2.126	19.35	2.179	18.04	2.170	18.12
Depth of Finished Block	8-7/16"		8-3/16"		7-14/16"		8-3/16"		8-7/16"		8-7/16"	

TABLE C-1

Mix:
Same as given in Table C.

HORIZONTAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

Location	FORMING PRESSURES IN LBS. PER S. IN.											
	500		1000		1500		2000		3000		4000	
Block	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
A	2.043	21.80	2.098	19.51	2.115	19.87	2.150	19.38	2.182	17.70	2.170	18.07
B	2.032	22.71	2.088	20.98	2.113	19.78	2.133	19.58	2.168	18.49	2.175	18.14
C	2.032	22.48	2.091	20.70	2.111	19.84	2.135	19.17	2.187	17.93	2.178	18.07
D	2.028	22.96	2.091	20.73	2.112	19.64	2.105	19.30	2.170	18.14	2.168	18.22
Avg. A-D	2.034	22.49	2.092	20.48	2.112	19.78	2.125	19.35	2.178	18.06	2.172	18.13
Block Thickness in in.	8-7/16"		8-3/16"		7-14/16"		8-3/16"		8-7/16"		8-7/16"	

TABLE D

Mix:
North Missouri Semi-Flint Clay 92%
Fire Brick Grog 8%
) Ground in Dry Pan - Through 8 Mesh.

VERTICAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURE IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
1	1.952	25.66	1.963	23.60	2.018	22.56	2.043	22.72	2.073	21.13	2.093	20.35
2	1.943	26.06	1.968	24.41	1.985	23.58	2.030	23.24	2.055	21.59	2.095	20.27
3	1.917	25.43	1.940	25.38	1.983	23.50	2.048	22.29	2.078	20.95	2.103	19.69
4	1.927	26.22	1.940	24.71	2.085	23.37	2.060	22.28	2.095	20.30	2.190	20.09
5	1.915	26.12	1.963	24.58	2.150	22.33	2.065	21.55	2.115	19.80	2.128	18.72
6	1.935	25.18	1.988	23.61	2.045	21.71	2.088	21.00	2.130	19.15	2.143	18.23
7	1.950	25.43	2.010	23.03	2.058	21.30	2.103	20.37	2.143	18.64	2.140	17.99
8	1.965	24.75	2.018	22.57	2.078	20.35	2.115	19.95	2.153	18.26	2.150	17.64
Avg. 1-8	1.938	25.73	1.974	24.01	2.050	22.34	2.069	21.68	2.105	19.98	2.128	19.12
Depth of Finished Block	10-5/16"		10-3/4"		10-5/16"		10-9/32"		10-1/32"		9-15/16"	

TABLE D-1

Mix:
Same as given in Table D.

HORIZONTAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURES IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
Block	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
A	1.931	25.70	1.971	24.17	2.030	22.51	2.074	21.63	2.103	20.06	2.135	19.35
B	1.950	25.36	1.983	23.92	2.065	22.08	2.070	21.67	2.108	19.96	2.126	19.20
C	1.933	26.04	1.971	24.20	2.057	22.22	2.071	21.58	2.106	19.85	2.125	18.98
D	1.937	25.63	1.967	23.76	2.047	22.66	2.060	21.95	2.104	20.03	2.123	18.97
Avg. A-D	1.938	25.71	1.973	24.01	2.050	22.37	2.069	21.71	2.105	19.98	2.128	19.13
Block Thickness	10-5/16"		10-3/4"		10-5/16"		10-9/32"		10-1/32"		9-15/16"	

TABLE E

Mix:
Cheltenham Clay 25%) Ground in Dry Pan - Through 8 Mesh.
No. 1 Missouri Flint Clay 75%)

VERTICAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURE IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
1	1.807	30.78	1.828	29.15	1.840	29.44	1.858	28.80	1.833	28.15	1.850	28.10
2	1.805	31.42	1.825	29.25	1.835	29.59	1.858	28.11	1.840	28.88	1.863	27.87
3	1.795	31.61	1.820	30.07	1.837	29.03	1.873	28.66	1.848	28.22	1.870	27.36
4	1.785	31.02	1.818	28.82	1.848	29.34	1.888	28.11	1.850	28.04	1.883	26.92
5	1.780	31.34	1.835	29.21	1.858	28.71	1.895	27.80	1.868	27.18	1.885	26.70
6	1.803	30.69	1.855	28.58	1.883	28.25	1.910	27.26	1.880	27.02	1.903	26.55
7	1.813	30.03	1.860	28.02	1.900	27.53	1.928	26.62	1.890	26.83	1.915	26.32
8	1.840	27.92	1.875	27.25	1.885	26.91	1.923	26.31	1.908	26.22	1.925	25.68
Avg. 1-8	1.804	30.60	1.837	28.79	1.861	28.38	1.880	27.83	1.865	27.37	1.887	26.95
Depth of Finished Block	11-1/8"		10-3/4"		10-5/8"		10-7/16"		10-11/16"		10-3/4"	

TABLE E-1

Mix:
Same as given in Table E.

HORIZONTAL VARIATION IN APPARENT POROSITY AND BULK DENSITY

FORMING PRESSURES IN LBS. PER SQ. IN.

Location	500		1000		1500		2000		3000		4000	
Block	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.	Sp.Gr.	Por.
A	1.805	30.66	1.838	28.95	1.870	28.39	1.894	27.61	1.856	27.67	1.895	26.67
B	1.801	30.98	1.835	29.01	1.865	28.67	1.891	27.95	1.870	27.38	1.888	26.89
C	1.809	30.37	1.840	28.89	1.864	28.76	1.895	27.86	1.861	27.41	1.881	27.02
D	1.799	30.40	1.843	25.09	1.861	28.73	1.888	27.95	1.858	27.80	1.883	27.21
Avg. A-D	1.804	30.60	1.839	27.96	1.865	28.64	1.892	27.83	1.861	27.57	1.887	26.95
Block Thickness	11-1/8"		10-3/4"		10-5/8"		10-7/16"		10-11/16"		10-3/4"	

GRAPHS

Discussion of Results

From the graph Plot A, it can be seen that in the vertical column, the 2000 lb. pressure application gave the best results for the building brick mix, consisting of St. Louis Surface Clay. Pressures of 500 lbs. and 1000 lbs. gave a softer core in the center of the block and is shown by the increase in porosity of the middle layers with the porosity decreasing on either end. This also shows that the pressure is first transmitted to the outside layers and only after more external pressure is applied, is it transmitted to the center. In the higher pressures, 3000 lbs. and 4000 lbs., the porosity decreased from top to bottom. This is undoubtedly due to the lower ram moving thru the greatest distance which would tend to force the grains to transmit the pressure first, as the lower side would be moving more than the top.

In Graph C is shown the most uniform porosity thruout the entire pressure range, though there was but little variation in porosity between pressures of 1000 lbs. and 2000 lbs. This mix gave the best results in regard to uniform porosity thruout the entire depth of the block.

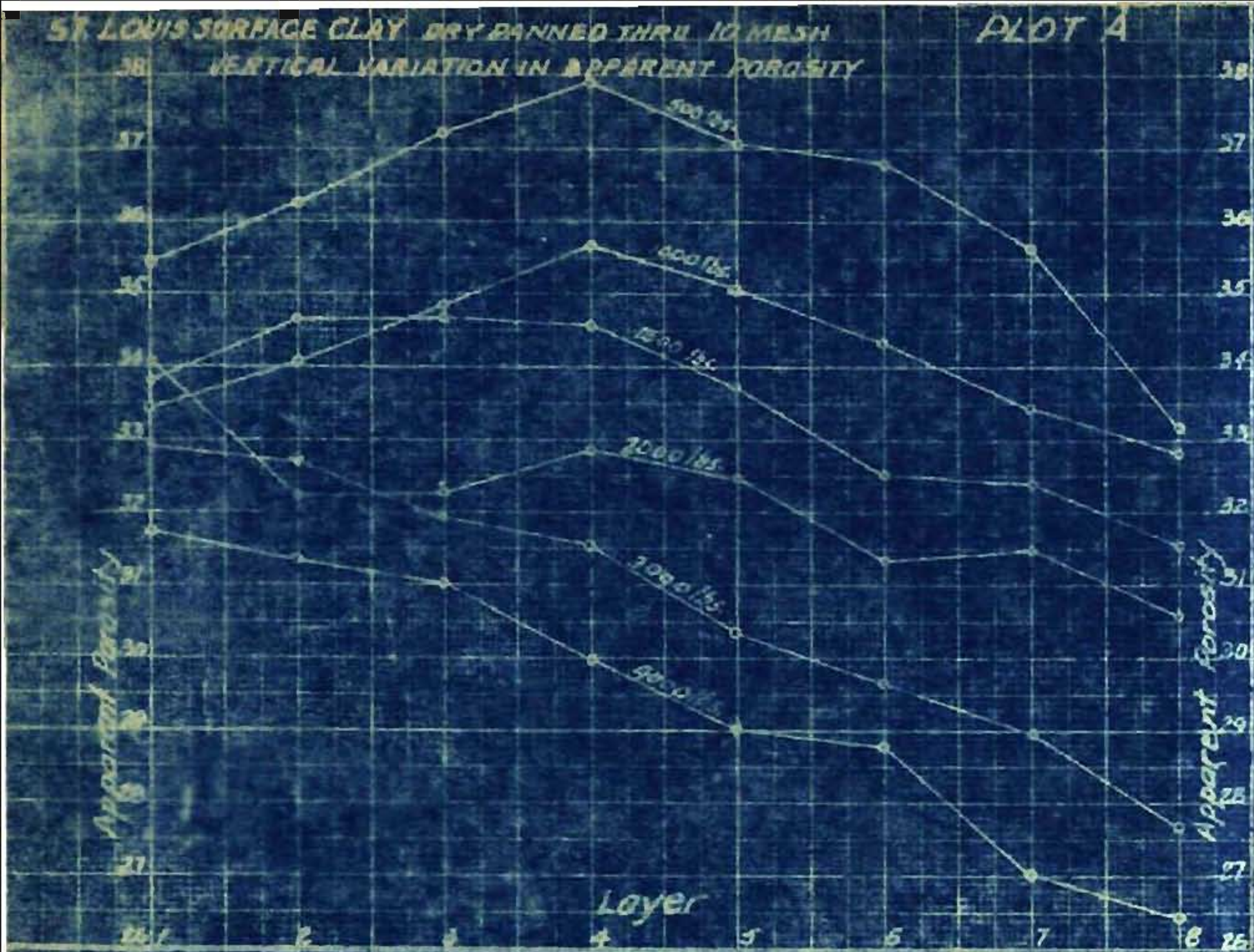
From the two types of mixes, that is, building brick and fire brick, it is seen that the fire brick mixes transmit the pressure more uniformly thruout the block than do the building brick. Thus another interesting problem is found as to the cause or causes of this difference, and to the remedy for this.

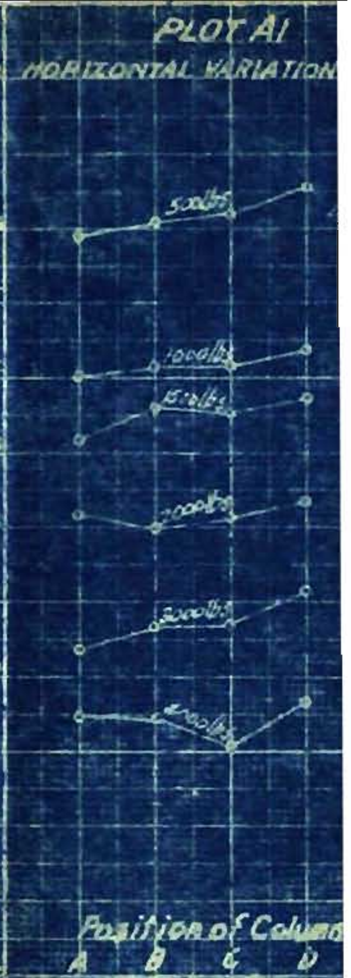
The porosity for the horizontal layers did not vary a great deal in either of the two types of mixes and so not much information can be obtained from this.

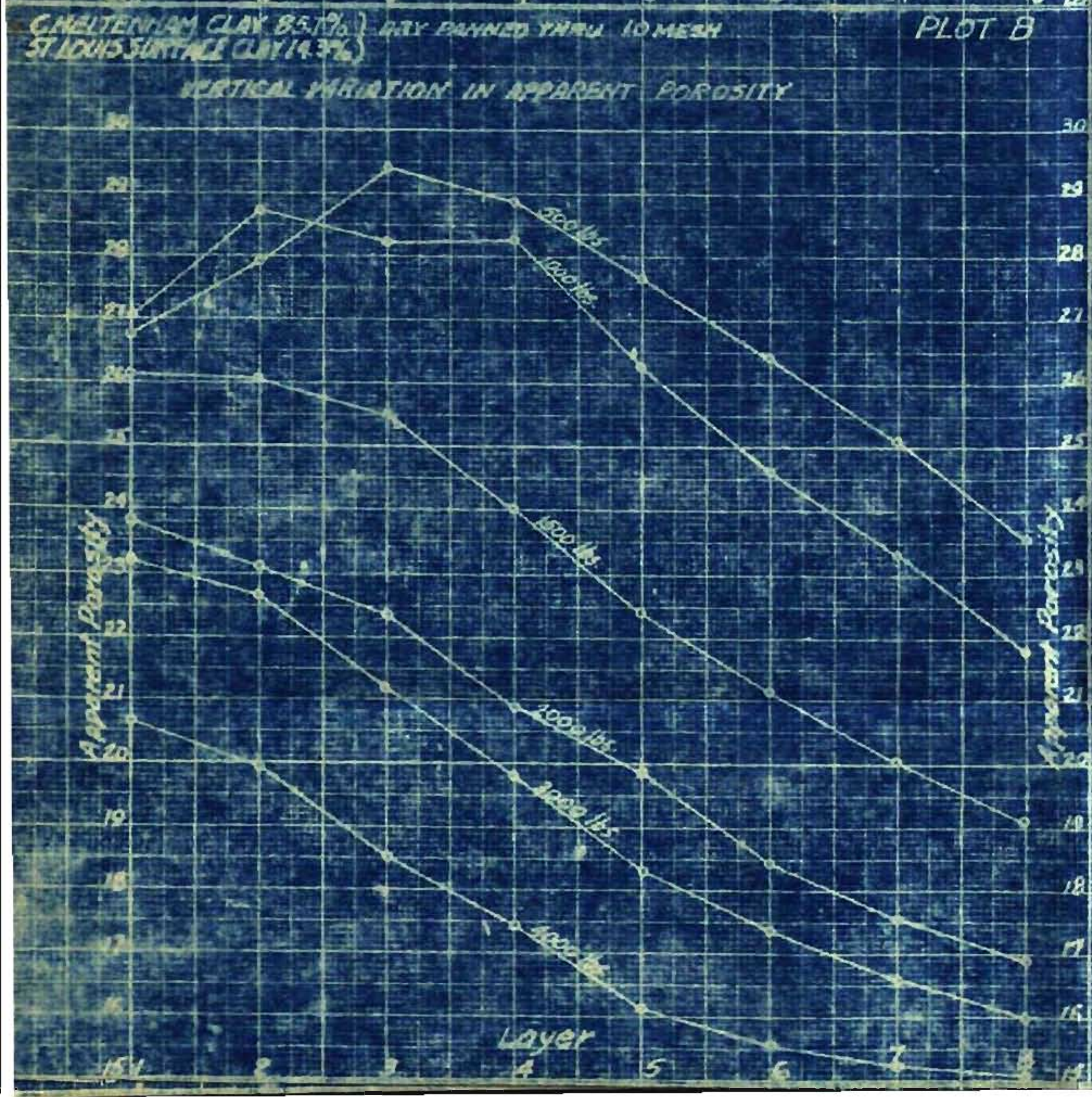
This difference in the ability of the fire brick mixes to transmit the pressures more readily than the building brick mix can be accounted for in several ways. From the screen analyses of the various mixes, it is noted that the St. Louis Surface Clay had 46% thru 200 mesh and the mixture of St. Louis and Cheltenham clays had 24%, while the fire brick mixes had a maximum of only 13%, thru 200 mesh. It may be assumed that this large amount of colloidal material in the building brick mixes may be one of the factors affecting the transmission. The non-plastic quality of those fines may also affect the transmission. It may also be brought to mind that this colloidal material is able to hold the entrapped air more readily and thus affect the pressure transmission.

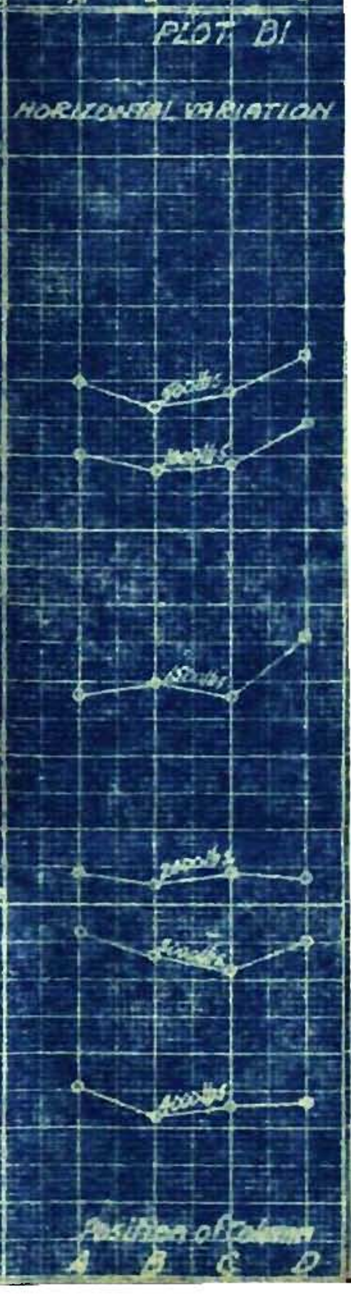
The shape of grain, size of grain and amount of the various sizes have an important effect. These sizes and shapes vary with the different clays and can only be controlled in the grinding of the clays.

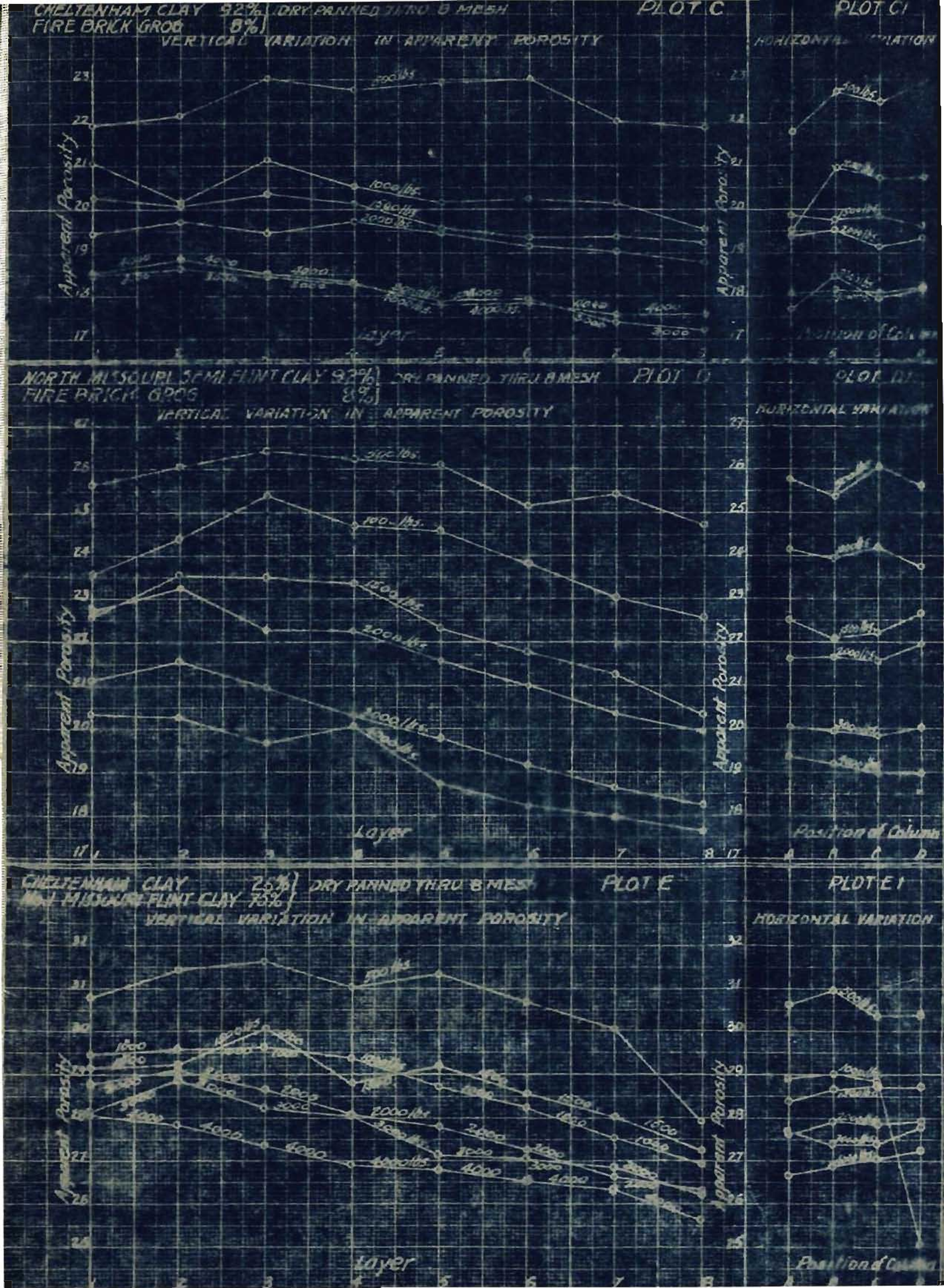
In conclusion, it may be said that the difference in the transmission of the two types of mixes, building brick and fire brick, is due largely to the size and shape of the grain and to the relatively non-plastic quality of the fines in the building brick mixes.


ST. LOUIS SURFACE CLAY DRY PANNED THRU 10 MESH
PLOT A
VERTICAL VARIATION IN APPARENT POROSITY
500 lbs.
1000 lbs.
1500 lbs
2000 lbs.
3000 lbs.
4000 lbs.
Apparent Porosity
Layer
1
2
3
4
5
6
7
8


PLOT A1
HORIZONTAL VARIATION
500 lbs
1000 lbs
1500 lbs
2000 lbs
3000 lbs
4000 lbs
Apparent Porosity
Position of Column
A
B
C
D


CHELTENHAM CLAY 85.7%
ST LOUIS SURFACE CLAY 14.3%
DRY PANNED THRU 10 MESH
PLOT B
VERTICAL VARIATION IN APPARENT POROSITY
500 lbs.
1000 lbs.
1500 lbs.
2000 lbs.
3000 lbs.
4000 lbs.
Apparent Porosity
Layer
1
2
3
4
5
6
7
8


PLOT B1
HORIZONTAL VARIATION
500 lbs
1000 lbs
1500 lbs
2000 lbs
3000 lbs
4000 lbs
Apparent Porosity
Position of Column
A
B
C
D


CHELTENHAM CLAY 92%
FIRE BRICK GROG 8%
DRY PANNED THRU 8 MESH
PLOT C
VERTICAL VARIATION IN APPARENT POROSITY
Apparent Porosity
Layer
PLOT C1
Position of Column
NORTH MISSOURI SEMI FLINT CLAY 92%
FIRE BRICK GROG 8%
DRY PANNED THRU 8 MESH
PLOT D
VERTICAL VARIATION IN APPARENT POROSITY
HORIZONTAL VARIATION
Apparent Porosity
Layer
Position of Column
CHELTENHAM CLAY 25%
MISSOURI FLINT CLAY 75%
DRY PANNED THRU 8 MESH
PLOT E
VERTICAL VARIATION IN APPARENT POROSITY
PLOT E1
HORIZONTAL VARIATION
Apparent Porosity
Layer
Position of Column

PART II

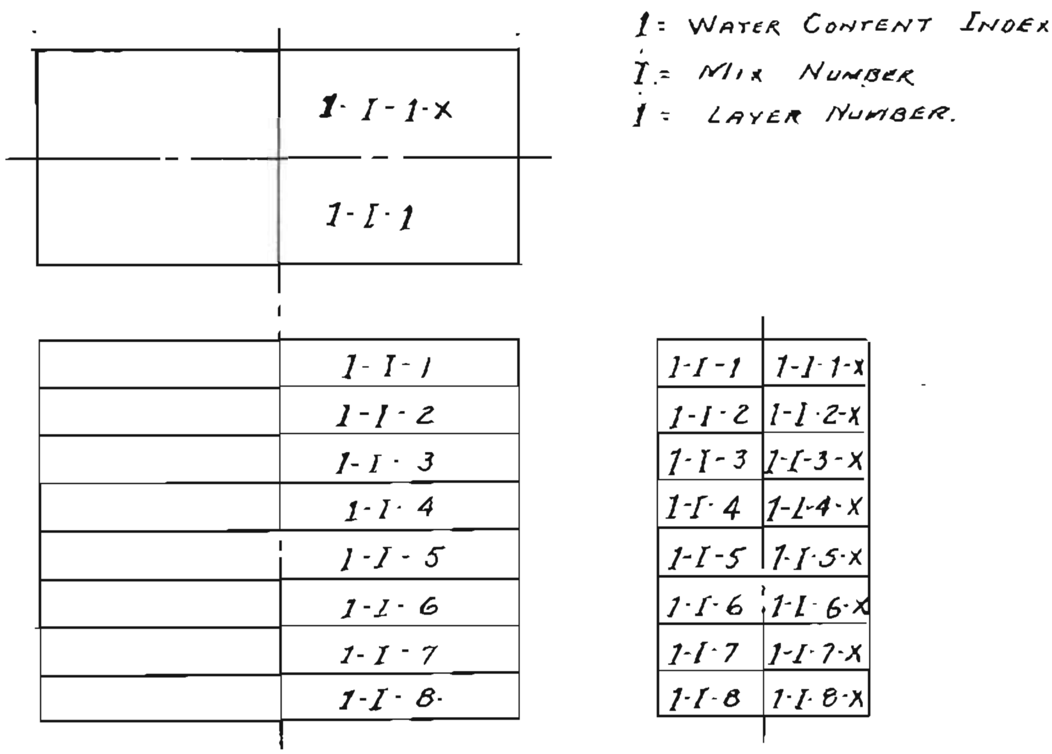
In this investigation the applied pressure was kept constant at 2000 lbs. and the moisture content varied from 5 to 12%, except in two cases, where 14% was added, but these gave poor results, due to the flowing of the mix thru the vent holes of the die when the maximum pressure was applied. No. 1 Mix consisted of 100% St. Louis Surface Clay; No. 2: 100% Cheltenham Clay; No. 3: 85.7% Cheltenham and 14.7% St. Louis Surface Clay; No. 4: 92% Cheltenham Clay and 8% Grog; No. 5: 92% North Missouri Semi-Flint and 8% Grog; and No. 6: 75% Missouri Flint and 25% Cheltenham.

FORMING

In forming these blocks, it was first necessary to find out the amount of clay necessary to fill the two inch mold box, as this varied with the moisture content, and with the mix. This amount ranged between 2-3/4 lbs. to 3-1/2 lbs. for each layer. This was introduced into the mold box by hand and a thin layer of flint sprinkled over it. Eight layers composed each block as in the preceding investigation. The pressure of 2000 lbs. was then applied and the maximum pressure held for 2 seconds.

DRYING

The blocks were first dried at room temperature for 5 days and then cut into samples and dried in an electric drier at 235^{o}F. These samples were cut different from those of the preceding part, there being only two samples to each layer instead of four. The position of these samples is shown in the following figure:



These samples were approximately 2-1/4" x 4-3/4" and composed one-half of the layer.

These samples were weighed and then soaked in kerosene at a reduced pressure of 26" of mercury in an autoclave. They were then weighed suspended in kerosene and saturated.

The bulk specific gravity and apparent porosity were determined as before.

$$\text{Bulk Specific Gravity} = \frac{\text{Weight Dry}}{\dfrac{\text{Weight Saturated} - \text{Weight Suspended}}{\text{Sp. Gr. of Kerosene}}}$$

$$\text{Apparent Porosity} = \frac{\text{Weight Saturated} - \text{Weight Dry}}{\text{Weight Saturated} - \text{Weight Suspended}}$$

These results are given in Tables I to XII inclusive and are represented on Graphs P to V inclusive.

The relation of apparent porosity to the water content of the mix is given in Tables I to XII and is represented on Graph N.

Samples on which the modulus of rupture was determined were also made. These consisted of brick made by filling a 2 inch mold box with clay and applying a pressure of 2000 lbs. After the pressure application, these pieces varied in thickness from 1" to 1-3/4", this variation being due principally to the water content of the different mixes. These pieces were broken on a Riehle Universal Machine of 50,000 lbs. capacity. The span between the brackets was 8 inches and the brackets had rounded edges to allow slippage on the underside of

TABLE I

Layer	1-I-1 App. Por.	1-I-1 Avg. App. Por.	2-I-1 App. Por.	2-I-1 Avg. App. Por.	3-I-1 App. Por.	3-I-1 Avg. App. Por.	4-I-1 App. Por.	4-I-1 Avg. App. Por.	5-I-1 App. Por.	5-I-1 Avg. App. Por.	6-I-1 App. Por.	6-I-1 Avg. App. Por.
1	33.33	30.18	31.17	30.86	29.82	29.32	29.31	29.73	29.27	29.17	.....	29.01
2	33.97	33.24	.....	33.37	31.47	31.58	30.00	30.22	29.21	29.07	29.57	29.22
3	35.84	34.45	12.55	32.92	29.81	30.41	30.02	30.97	.....	29.88	29.88	29.92
4	35.14	33.14	32.00	31.94	26.30	27.30	30.07	30.53	30.37	30.37	29.73	29.51
5	32.81	33.07	31.98	31.83	30.68	29.94	29.78	30.00	29.60	29.58	28.69	29.25
6	32.48	32.05	31.21	30.91	29.80	30.02	28.79	29.00	29.39	29.11	29.39	29.70
7	30.63	31.82	32.69	31.70	29.08	29.26	.....	28.19	28.88	28.88	28.84	28.94
8	.....	32.31	30.48	30.35	29.52	29.52	28.39	28.39	27.80	27.91	28.48	28.88
X												
1	27.02	.....	30.55	.....	28.82	.....	29.95	.....	29.08	.....	29.01	.....
2	32.51	.....	33.37	.....	31.69	.....	30.43	.....	28.93	.....	28.86	.....
3	35.05	.....	32.92	.....	31.00	.....	31.02	.....	29.68	.....	29.97	.....
4	33.14	.....	31.89	.....	28.21	.....	31.00	.....	.....	.....	29.30	.....
5	33.38	.....	31.67	.....	29.27	.....	30.21	.....	29.55	.....	29.81	.....
6	31.63	.....	30.61	.....	30.24	.....	29.20	.....	28.83	.....	30.00	.....
7	35.00	.....	30.71	.....	29.50	.....	28.10	.....	34.96	.....	29.05	.....
8	32.31	.....	30.18	.....	.....	.....	.....	.....	28.01	.....	28.67	.....
Total Avg. App. Porosity		32.53		31.73		29.03		29.03		29.80		29.27

TABLE II

Layer	1-II-1 App. Por.	1-II-1 Avg. App. Por.	2-II-1 App. Por.	2-II-1 Avg. App. Por.	3-II-1 App. Por.	3-II-1 Avg. App. Por.	4-II-1 App. Por.	4-II-1 Avg. App. Por.	5-II-1 App. Por.	5-II-1 Avg. App. Por.	6-II-1 App. Por.	6-II-1 Avg. App. Por.
1	22.39	22.39	21.57	21.59	18.92	18.75	17.61	17.61	20.00	20.69	.....	20.7[illegible]
2	21.69	21.36	22.76	22.54	18.19	18.07	18.61	18.73	18.95	19.87	22.59	21.8[illegible]
3	24.12	24.15	23.41	21.98	18.85	18.43	21.10	21.13	21.23	20.38	20.33	21.1[illegible]
4	23.41	23.61	19.34	20.29	17.16	17.94	19.59	20.06	21.20	21.40	22.65	22.03
5	21.79	22.39	16.92	20.00	18.31	18.17	19.98	19.32	21.47	22.05	21.90	21.2[illegible]
6	.....	21.77	18.79	18.97	18.66	18.78	17.94	18.51	21.64	21.31	20.19	20.50
7	21.20	21.50	18/12	18.14	17.60	18.73	19.90	19.60	22.03	21.78	21.05	20.9[illegible]
8	19.08	20.46	17.62	17.99	17.02	18.51	.....	.....	21.18	20.58	22.21	22.2[illegible]
X												
1	.....	.....	21.62	.....	18.79	.....	.....	.....	21.38	.....	20.75	.....
2	21.13	.....	22.29	.....	17.95	.....	18.85	.....	20.60	.....	21.59	.....
3	24.18	.....	20.54	.....	18.10	.....	21.17	.....	19.53	.....	22.03	.....
4	23.80	.....	21.25	.....	18.71	.....	20.52	.....	21.61	.....	21.41	.....
5	23.00	.....	20.00	.....	17.93	.....	18.67	.....	22.57	.....	20.58	.....
6	21.77	.....	19.15	.....	18.84	.....	19.08	.....	20.98	.....	20.60	.....
7	21.81	.....	18.17	.....	19.85	.....	19.30	.....	21.62	.....	20.82	.....
8	20.00	.....	18.36	.....	20.00	.....	.....	.....	19.85	.....	22.20	.....
Total Avg. App. Porosity		22.20		20.19		18.42		19.28		21.00		21.3[illegible]

TABLE III

Layer	1-III-1 App. Por.	1-III-1 Avg. App. Por.	2-III-1 App. Por.	2-III-1 Avg. App. Por.	3-III-1 App. Por.	3-III-1 Avg. App. Por.	4-III-1 App. Por.	4-III-1 Avg. App. Por.	5-III-1 App. Por.	5-III-1 Avg. App. Por.	6-III-1 App. Por.	6-III-1 Avg. App. Por.
1	20.61	21.14	22.30	21.34	21.00	19.27	20.34	20.17	18.32	18.59	.....	.....
2	22.01	22.04	22.04	21.17	20.28	21.15	20.82	20.51	19.05	18.98	.....	.....
3	23.30	22.39	23.87	22.79	19.29	19.77	19.71	20.66	22.30	20.80	.....	.....
4	21.40	21.17	19.06	19.45	20.69	19.80	19.18	19.59	20.57	19.68	23.17	21.89
5	20.15	20.86	20.61	20.34	.....	19.20	18.93	19.42	20.15	20.15	20.27	19.81
6	20.19	20.61	19.00	19.17	19.14	19.43	19.50	19.69	18.90	19.07	20.94	21.54
7	20.00	19.85	23.64	17.94	19.37	19.61	19.70	20.86	19.52	19.43	20.00	20.90
8	18.26	18.33	17.76	17.76	19.37	19.28	20.37	20.34	.....	18.90	21.88	21.86
X												
1	21.67	.....	20.39	.....	18.94	.....	20.00	.....	18.86	.....	.....	.....
2	22.06	.....	20.30	.....	22.02	.....	20.21	.....	18.90	.....	.....	.....
3	21.49	.....	21.71	.....	20.25	.....	21.68	.....	19.30	.....	.....	.....
4	20/94	.....	19.85	.....	18.91	.....	20.00	.....	18.80	.....	20.62	.....
5	21.59	.....	20.06	.....	19.20	.....	19.90	.....	20.16	.....	19.55	.....
6	21.02	.....	19.34	.....	19.72	.....	19.79	.....	19.24	.....	22.14	.....
7	19.69	.....	17.94	.....	19.85	.....	22.02	.....	19.33	.....	21.00	.....
8	18.40	.....	.....	.....	19.18	.....	20.30	.....	18.90	.....	21.85	.....
Total Avg. App. Porosity		20.80		19.99		19.78		20.15		19.45		21.22

TABLE IV

Layer	1-IV-1 App. Por.	1-IV-1 Avg. App. Por.	2-IV-1 App. Por.	2-IV-1 Avg. App. Por.	3-IV-1 App. Por.	3-IV-1 Avg. App. Por.	4-IV-1 App. Por.	4-IV-1 Avg. App. Por.	5-IV-1 App. Por.	5-IV-1 Avg. App. Por.	6-IV-1 App. Por.	6-IV-1 Avg. App. Por.	7-IV-1 App. Por.	7-IV-1 Avg. App. Por.
1	20.30	21.90	23.08	22.37	18.75	18.88	18.16	18.47	20.33	20.75	22.02	22.02	.....	.....
2	23.90	22.35	22.94	23.13	17.27	17.70	18.18	18.97	20.16	19.75	20.81	20.32	.....	.....
3	23.24	23.23	21.41	21.27	17.14	17.57	17.57	18.16	19.82	19.53	20.31	20.31	.....	.....
4	25.90	22.98	22.43	22.49	17.98	18.50	18.70	18.80	19.36	19.84	20.81	22.08	.....	.....
5	22.22	22.54	20.89	20.95	17.81	18.42	20.27	19.60	20.50	21.13	21.08	21.00	20.24	19.93
6	20.34	21.88	21.00	20.70	17.99	18.04	18.95	19.24	20.87	20.85	21.90	21.95	22.13	21.63
7	21.75	22.45	21.03	20.57	18.78	18.89	18.93	19.02	20.17	20.65	21.08	20.51	21.44	21.22
8	20.00	20.48	19.30	19.36	18.00	18.08	19.40	19.27	18.64	18.90	20.95	19.77	20.63	20.65
X														
1	23.50	.....	21.46	.....	19.02	.....	18.78	.....	21.16	.....	25.41	.....	.....	.....
2	21.80	.....	23.51	.....	18.12	.....	17.96	.....	19.35	.....	19.84	.....	.....	.....
3	23.22	.....	21.13	.....	18.00	.....	18.76	.....	19.24	.....	20.38	.....	.....	.....
4	22.06	.....	22.54	.....	19.02	.....	18.90	.....	20.33	.....	23.55	.....	.....	.....
5	22.86	.....	21.00	.....	19.02	.....	18.93	.....	21.76	.....	20.98	.....	19.63	.....
6	22.10	.....	20.40	.....	18.08	.....	19.54	.....	21.44	.....	21.99	.....	21.22	.....
7	23.12	.....	20.12	.....	19.00	.....	19.11	.....	21.12	.....	20.00	.....	21.00	.....
8	20.95	.....	19.43	.....	18.12	.....	19.14	.....	19.15	.....	17.59	.....	.....	.....
Total Avg. App. Porosity		22.14		21.34		18.25		18.83		20.17		20.99		20.85

<u>TABLE V</u>

Layer	1-V-1 App. Por.	1-V-1 Avg. App. Por.	2-V-1 App. Por.	2-V-1 Avg. App. Por.	3-V-1 App. Por.	3-V-1 Avg. App. Por.	4-V-1 App. Por.	4-V-1 Avg. App. Por.	5-V-1 App. Por.	5-V-1 Avg. App. Por.	6-V-1 App. Por.	6-V-1 Avg. App. Por.
1	.....	18.10	.....	.....	18.24	18.29	18.42	18.42	19.46	20.24	.....	22.76
2	.....	.....	20.28	20.28	20.53	19.49	19.09	18.34	21.97	20.03	21.90	21.85
3	.....	.....	21.39	22.33	18.15	17.64	18.80	18.45	21.40	20.82	21.82	21.64
4	21.32	21.50	.....	21.67	19.17	20.28	18.49	18.82	21.02	19.84	21.00	21.43
5	22.00	21.51	20.86	21.18	17.00	18.50	20.00	19.48	21.99	21.51	22.61	22.33
6	19.35	20.23	19.89	20.64	18.69	19.13	19.09	19.39	21.61	20.26	21.79	22.28
7	20.21	20.21	20.60	20.30	19.75	19.00	19.10	18.95	17.14	18.69	22.17	21.69
8	19.09	19.44	21.41	20.71	18.32	18.21	18.45	18.35	20.63	20.86	21.36	21.70
X												
1	18.10	.....	.....	.....	18.33	.....	.....	.....	21.01	.....	22.78	.....
2	.....	.....	.....	.....	18.45	.....	17.89	.....	18.84	.....	21.40	.....
3	.....	.....	23.34	.....	17.14	.....	18.10	.....	20.24	.....	21.46	.....
4	21.68	.....	21.67	.....	21.38	.....	19.15	.....	18.66	.....	22.46	.....
5	20.98	.....	21.50	.....	20.00	.....	18.96	.....	21.02	.....	22.06	.....
6	21.17	.....	21.39	.....	19.57	.....	19.69	.....	18.92	.....	22.77	.....
7	20.21	.....	20.00	.....	18.26	.....	18.80	.....	16.24	.....	21.21	.....
8	19.78	.....	20.00	.....	17.90	.....	18.25	.....	21.08	.....	22.21	.....
Total Avg. App. Porosity		20.17		21.02		18.82		18.77		20.14		21.05

TABLE VI

Layer	1-VI-1 App. Por.	1-VI-1 Avg. App. Por.	2-VI-1 App. Por.	2-VI-1 Avg. App. Por.	3-VI-1 App. Por.	3-VI-1 Avg. App. Por.	4-VI-1 App. Por.	4-VI-1 Avg. App. Por.	5-VI-1 App. Por.	5-VI-1 Avg. App. Por.	6-VI-1 App. Por.	6-VI-1 Avg. App. Por.	7-VI-1 App. Por.	7-VI-1 Avg. App. Por.
1	28.38	26.19	27.04	26.44	25.59	25.75	29.38	28.66	28.10	28.22	29.71	29.33	27.42	27.99
2	25.92	24.96	26.80	26.62	26.02	25.81	29.63	28.01	(8.16)	28.10	28.82	28.70	27.00	27.75
3	27.88	27.73	27.05	26.92	26.61	26.35	27.21	28.35	28.18	27.87	27.69	27.49	27.01	27.91
4	28.78	28.30	25.78	26.30	25.91	26.14	29.79	30.00	28.20	29.01	28.78	28.59	28.17	28.16
5	28.21	27.61	26.95	27.08	26.80	26.30	29.01	28.82	29.48	29.51	27.69	27.80	27.01	27.34
6	27.82	27.54	26.59	27.60	26.10	25.74	29.74	28.68	29.59	29.00	26.67	27.06	26.50	25.96
7	27.44	27.35	26.30	26.24	25.52	25.77	25.80	27.00	29.42	28.73	25.82	26.38	26.12	25.97
8	26.52	26.78	26.81	26.25	25.56	25.71	28.42	28.09	.....	.....	25.90	25.99	26.22	25.72
X														
1	24.00	.....	25.84	.....	25.90	.....	27.75	.....	28.34	.....	28.96	.....	28.56	.....
2	24.00	.....	26.43	.....	25.61	.....	26.59	.....	28.10	.....	28.58	.....	28.48	.....
3	27.58	.....	26.76	.....	26.08	.....	29.50	.....	27.56	.....	27.59	.....	28.22	.....
4	27.81	.....	26.83	.....	26.38	.....	30.21	.....	29.81	.....	28.41	.....	28.19	.....
5	27.00	.....	27.20	.....	25.80	.....	28.62	.....	29.54	.....	27.80	.....	27.67	.....
6	27.26	.....	26.02	.....	25.37	.....	27.62	.....	28.41	.....	27.55	.....	25.61	.....
7	27.26	.....	26.18	.....	26.01	.....	28.21	.....	28.03	.....	26.95	.....	25.82	.....
8	27.04	.....	25.68	.....	25.86	.....	27.76	.....	.....	.....	26.08	.....	25.21	.....
Total Avg. App. Porosity		27.06		26.68		27.20		28.44		28.65		27.67		27.10

TABLE VII

Mix I	Wt. Dry	Wt. Sat.	Wt. Sus.	Wt. Sat.-Wt. Sus.	Wt. Sat.-Wt. Dry	Bulk Sp. Gr.	Avg. Bulk Sp. Gr.	Porosity	Average Porosity
5-1-1X	1346	1522	937	585	186	1.872)	1.873	31.80)	30.89
5-1-1	1392	1573	968	605	181	1.874)		29.98)	
6-1-1X	1262	1427	881	546	165	1.879)	1.880	30.20)	29.85
6-1-1	1472	1662	1026	636	190	1.881)		29.90)	
6-1-2X	1267	1430	883	547	163	1.880)		29.83)	
6-1-2	1398	1576	972	604	178	1.880)		29.50)	
8-1-1X	1360	1526	947	579	166	1.909)	1.911	28.70)	28.81
8-1-1	1231	1380	859	521	149	1.920)		28.64)	
8-1-2X	1262	1417	880	537	155	1.915)		28.82)	
8-1-2	1380	1552	962	590	172	1.900)		29.10)	
9-1-1X	1367	1530	953	577	163	1.945)	1.932	28.25)	28.82
9-1-1	1273	1431	886	545	160	1.920)		29.40)	
10-1-1X	1349	1512	937	575	163	1.920)	1.924	28.21)	28.03
10-1-1	1295	1449	899	550	154	1.918)		28.00)	
10-1-2X	1383	1545	960	585	162	1.950)		27.70)	
10-1-2	1444	1618	1002	616	174	1.909)		28.21)	
12-1-1X	1457	1650	1010	640	193	1.850)	1.850	30.10)	30.10

TABLE VIII

Mix II	Wt. Dry	Wt. Sat.	Wt. Sus.	Wt. Sat.- Wt. Sus.	Wt. Sat.- Wt. Dry	Bulk Sp. Gr.	Avg. Bulk Sp. Gr.	Porosity	Average Porosity
5-2-1X	1519	1611	1050	561	92	2.200		16.38	
5-2-2	1772	1879	1225	654	107	2.195	2.200	16.35	16.51
5-2-2X	1589	1687	1098	589	98	2.195		16.65	
5-2-2	1507	1600	1043	557	93	2.210		16.66	
6-2-1X	1651	1748	1141	607	97	2.218		15.95	
6-2-1	1543	1636	1067	569	93	2.205	2.202	16.52	16.30
6-2-2X	1544	1640	1067	573	96	2.195		16.72	
6-2-2	1552	1647	1071	576	95	2.195		16.50	
9-2-1X	1221	1306	846	460	85	2.158		18.49	
9-2-1	1323	1413	915	498	90	2.161	2.163	18.05	18.16
9-2-2	1248	1332	865	467	84	2.175		17.95	
10-2-1X	1118	1189	769	420	77	2.155	2.162	18.38	18.47
10-2-1	1260	1348	876	472	88	2.170		18.60	
12-2-1X	1170	1259	774	485	89	1.964	2.036	18.55	19.22
12-2-1	1038	1119	719	400	81	2.109		20.20	

TABLE IX

Mix III

	Wt. Dry	Wt. Sat.	Wt. Sus.	Wt. Sat. - Wt. Sus.	Wt. Sat - Wt. Dry	Bulk Sp.Gr.	Average Bulk Sp.Gr.	Porosity	Average Porosity
5-3-1X	1771	1906	1225	681	135	2.115		19.82	
5-3-1	1803	1940	1248	692	137	2.200	2.115	19.80	20.21
5-3-2X	1684	1818	1168	650	134	2.110		20.60	
5-3-2	1532	1656	1051	605	124	2.060		20.50	
6-3-1X	1685	1800	1171	629	115	2.100		18.30	
6-3-1	1519	1622	1056	566	103	2.180	2.180	18.20	18.15
6-3-2X	1694	1806	1174	633	103	2.190		18.25	
6-3-2	1578	1683	1094	589	105	2.180		17.85	
8-3-1X	1471	1565	1016	549	94	2.181		17.16	
8-3-1	1506	1604	1041	563	98	2.178	2.172	17.39	17.55
8-3-2X	1508	1608	1042	566	100	2.165		17.65	
8-3-2	1537	1641	1062	579	104	2.160		17.99	
9-3-1X	1396	1493	968	525	97	2.160		18.46	
9-3-1	1377	1474	957	517	97	2.170	2.161	18.72	18.84
9-3-2X	1430	1536	994	542	106	2.150		19.55	
9-3-2	1363	1480	960	520	97	2.165		18.65	
10-3-1X	1320	1418	915	503	98	2.135		19.43	
10-3-1	1248	1340	866	474	92	2.145	2.137	19.43	19.44
10-3-2X	1154	1239	800	439	85	2.140		19.37	
10-3-2	1154	1240	800	440	86	2.138		19.55	

TABLE X

Mix IV	Wt.Dry	Wt.Sat.	Wt.Sus.	Wt.Sat.-Wt.Sus.	Wt.Sat.-Wt.Dry	Bulk Sp.Gr.	Avg.Bulk Sp.Gr.	Porosity	Average Porosity
5-4-1X	1715	1843	1189	654	128	2.132		19.61	
5-4-1	1798	1932	1240	686	134	2.130	2.1315	19.50	19.79
5-4-2X	1528	1646	1061	585	118	2.134		20.20	
5-4-2	1671	1798	1159	639	127	2.130		19.85	
6-4-1X	1609	1724	1118	606	115	2.152		19.00	
6-4-1	1680	1801	1166	635	121	2.144	2.142	19.05	19.03
6-4-2X	1767	1893	1225	668	126	2.142		18.85	
6-4-2	1605	1722	1115	609	117	2.141		19.21	
8-4-1X	1446	1559	1003	556	113	2.112		20.30	20.12
8-4-1	1427	1536	991	546	109	2.130	2.119	20.00	
8-4-2X	1546	1664	1074	590	118	2.118		20.00	
8-4-2	1426	1537	989	548	111	2.116		20.20	
9-4-1X	1273	1373	885	488	100	2.112		21.40	
9-4-1	1295	1400	899	501	105	2.100	2.107	20.92	20.39
9-4-2X	1386	1486	961	525	100	2.142		19.05	
9-4-2	1156	1247	802	445	91	2.075		20.21	
10-4-1X	1143	1238	792	446	95	2.087		21.22	
10-4-1	1108	1200	769	431	92	2.094	2.083	21.32	21.46
10-4-2X	1116	1211	774	437	95	2.078		21.65	
10-4-2	922	1000	639	361	78	2.074		21.65	
12-4-1X	921	1007	638	369	86	2.032	2.030	23.30	23.51
12-4-1	1008	1102	698	404	94	2.028		23.51	

TABLE XI

Mix V	Wt. Dry	Wt. Sat.	Wt. Sus.	Wt. Sat.-Wt. Sus.	Wt. Sat.-Wt. Dry	Bulk Sp. Gr.	Average Bulk Sp. Gr.	Porosity	Average Porosity
5-5-1X	1868	2015	1293	722	147	2.110		20.37	
5-5-1	2144	2307	1486	821	163	2.140	2.122	19.81	20.09
5-5-2X	1949	2099	1352	747	150	2.121		20.10	
5-5-2	1960	2112	1356	756	152	2.120		20.10	
6-5-1X	1701	1827	1180	747	126	1.858	2.132	16.86	19.65
6-5-1	1807	1942	1253	689	135	2.132		19.05	
8-5-1X	1544	1656	1072	584	112	2.122		19.20	
8-5-1	1462	1565	1012	553	103	2.144	2.133	18.61	18.96
8-5-2X	1509	1618	1045	573	109	2.133		19.00	
8-5-2	1500	1608	1040	568	108	2.143		19.03	
9-5-1X	1419	1525	984	541	106	2.124		19.58	
9-5-1	1468	1580	1019	561	112	2.123	2.127	19.95	19.70
9-5-2X	1468	1579	1018	561	111	2.123		19.75	
9-5-2	1376	1478	956	522	102	2.140		19.55	
10-5-1X	1382	1493	958	535	111	2.070		20.73	
10-5-1	1369	1479	949	530	110	2.092	2.098	20.78	20.52
10-5-2X	1318	1421	914	507	103	2.112		20.30	
10-5-2	1349	1456	935	521	107	2.120		20.30	
12-5-1X	1129	1224	782	442	95	2.072		21.42	
12-5-1	1121	1217	777	440	96	2.071	2.074	21.80	21.78
12-5-2X	1136	1233	786	447	97	2.060		21.70	
12-5-2	1105	1199	766	433	94	2.090		21.70	

TABLE XII

Mix VI	Wt.Dry	Wt.Sat.	Wt.Sus.	Wt.Sat.−Wt.Sus.	Wt.Sat.−Wt.Dry	Bulk Sp.Gr.	Avg. Bulk Sp.Gr.	Por.	Avg.Por.
5-6-1	1888	1297	2099	802	211	1.910		26.30	
5-6-2X	1850	1272	2062	790	212	1.905	1.908	26.81	26.67
5-6-2	1815	1251	2023	772	208	1.910		26.92	
6-6-1X	1650	1136	1839	703	189	1.904		26.92	
6-6-1	1903	1323	2123	800	220	1.940	1.917	27.50	27.23
6-6-2X	1851	1281	2068	787	217	1.925		27.60	
6-6-2	1666	1144	1858	714	192	1.900		26.90	
8-6-1X	2003	2241	1387	854	238	1.923		27.80	
8-6-1	1418	981	1582	601	164	1.916	1.918	27.22	27.16
8-6-2X	1657	1148	1851	705	194	1.910		27.61	
8-6-2	1737	1196	1927	731	190	1.925		26.00	
9-6-1X	1784	1238	1981	743	197	1.956		26.23	
9-6-1	1631	1130	1821	691	190	1.926	1.931	27.48	27.06
9-6-2X	1818	2021	1256	765	206	1.932		26.23	
9-6-2	1602	1795	1111	684	193	1.910		28.30	
10-6-1X	1776	1228	1969	741	193	1.942		26.05	
10-6-1	1627	1125	1804	679	177	1.948	1.943	26.10	26.18
10-6-2X	1894	1309	2104	795	210	1.939		26.40	
12-6-1X	1237	856	1368	512	131	1.904	1.969	25.60	25.66
12-6-1	1570	1090	1736	646	166	1.975		25.73	
14-6-1X	1138	786	1261	475	123	1.945		26.10	
14-6-1	1370	947	1518	571	148	1.948	1.943	25.90	26.00
14-6-2	1175	811	1303	492	128	1.938		26.00	

TABLE XIII

Mix I

	Wt. Wet	Thickness When Formed	Wt. Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-1-1	2949	1.95	2738	1.95	4.76	465	815	3.80	18.05	309.1)	299.3
5-1-1	2991	1.95	2773	1.95	4.78	430	815	3.84	18.20	289.5)	
6-1-1	2968	1.94	2733	1.93	4.74	410	815	3.73	17.65	276.1)	311.0
6-1-1	2888	1.90	2662	1.87	4.73	480	815	3.52	16.65	346.0)	
8-1-1	2870	1.80	2588	1.80	4.74	510	815	3.24	15.38	398.6)	384.4
8-1-2	2926	1.85	2640	1.83	4.72	490	815	3.35	15.85	370.2)	
9-1-1	2988	1.87	2661	1.83	4.72	430	815	3.35	15.85	333.0)	340.0
9-1-2	2907	1.88	2592	1.83	4.73	475	815	3.35	15.87	359.0)	
10-1-1	3013	1.86	2827	1.85	4.71	430	815	3.42	16.10	320.5)	317.0
10-1-2	3212	2.00	2806	1.97	4.72	465	815	3.78	17.80	313.5)	
12-1-1	2767	....	2344	1.79	4.67	305	815	3.21	14.50	282.5)	282.5

TABLE XIV

Mix II

	Wt. Wet	Thickness When Formed	Wt. Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-2-1	3537	2.04	3285	2.01	4.70	425	815	4.00	18.80	271.8)	275.9
5-2-2	3534	1.90	3091	1.87	4.70	385	815	3.52	16.50	280.0)	
6-2-1	3447	1.97	3193	1.96	4.70	475	815	3.84	18.01	316.9)	295.4
6-2-2	3358	1.94	3095	1.88	4.69	375	815	3.52	16.50	273.0)	
8-2-1	3154	1.83	2870	1.80	4.66	285	815	3.24	15.10	226.3)	258.1
8-2-2	3155	1.84	2857	1.80	4.66	365	815	3.24	15.10	290.0)	
9-2-1	2822	1.63	2540	1.58	4.63	200	815	2.50	11.60	269.0)	291.4
9-2-2	2870	1.69	2584	1.65	4.64	330	815	2.73	12.65	313.8)	
10-2-1	2649	1.57	2371	1.50	4.62	220	700	2.25	10.40	254.0)	254.0
12-2-1	2505	1.53	2306	1.47	4.57	195	300	2.16	9.90	236.0)	236.0

TABLE XV

Mix III

	Wt. Wet	Thickness When Formed	Wt. Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-3-1	3798	2.26	3533	2.25	4.72	475	815	5.07	23.95	238.0	235.0
5-3-2	3410	2.05	3215	2.05	4.73	390	815	4.25	20.50	233.0	
6-3-1	3486	1.99	3207	1.98	4.70	555	815	3.93	18.50	359.2	361.7
6-3-2	3533	2.04	3237	2.00	4.70	570	815	4.00	18.80	364.2	
8-3-1	3281	1.89	2882	1.86	4.68	410	815	3.46	16.20	304.2	354.2
8-3-2	3349	1.94	3051	1.91	4.69	460	815	3.64	17.10	315.0	
9-3-1	3077	1.79	2777	1.79	4.66	415	815	3.20	14.95	333.0	335.2
9-3-2	3139	1.82	2830	1.80	4.66	425	815	3.24	15.10	337.5	
10-3-1	2863	1.69	2561	1.63	4.62	205	815	2.66	12.30	201.0	197.5
10-3-2	2584	1.54	2304	1.49	4.64	165	675	2.22	10.20	194.0	

TABLE XVI

Mix IV

	Wt. Wet	Thickness When Formed	Wt. Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-4-1	3763	2.21	3527	2.20	4.72	295	815	4.85	22.90	154.9)	155.2
5-4-2	3448	2.06	3211	2.02	4.73	250	815	4.08	19.30	155.5)	
6-4-1	3669	2.07	3293	2.03	4.73	275	815	4.15	19.50	169.0)	179.0
6-4-2	3654	2.12	3376	2.09	4.73	325	815	4.36	20.60	189.0)	
8-4-1	3160	1.83	2868	1.80	4.70	185	815	3.24	15.20	146.2)	146.1
8-4-2	3268	1.90	2976	1.87	4.70	200	815	3.50	16.46	146.0)	
9-4-1	2857	1.67	2573	1.65	4.69	125	815	2.72	12.80	117.2)	131.6
9-4-2	2830	1.64	2551	1.62	4.67	150	815	2.62	12.25	147.0)	
10-4-1	2530	1.52	2258	1.46	4.65	80	600	2.12	9.85	97.5)	106.2
10-4-2	2291	1.36	2039	1.34	4.63	80	600	1.79	8.34	115.0)	
12-4-1	2222	1.38	1939	1.37	4.57	75	100	1.88	8.65	104.0)	104.0

Mix V

TABLE XVII

	Weight Wet	Thickness When Formed	Weight Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-5-1	4275		4045	2.53	4.75	275	815	6.40	34.00	97.1	100.4
5-5-2	4157		3923	2.45	4.75	240	815	6.00	28.40	103.7	
6-5-1	3745		3509	2.18	4.74	235	815	4.75	22.50	135.7	128.3
6-5-2	3762		3543	2.20	4.75	235	815	4.84	22.80	120.9	
8-5-1	3300		3041	1.87	4.75	200	815	3.49	16.55	145.0	143.3
8-5-2	3267		3011	1.87	4.72	195	815	3.49	16.51	141.7	
9-5-1	3166		2889	1.81	4.70	165	815	3.28	15.40	128.5	136.3
9-5-2	3116		2846	1.79	4.70	190	815	3.20	15.00	144.0	
10-5-1	3047		2758	1.76	4.70	150	815	3.10	14.55	123.8	137.5
10-5-2	2970		2686	1.72	4.71	175	815	2.96	13.00	151.2	
12-5-1	2525		2252	1.47	4.67	95	675	2.16	10.01	114.0	117.5
12-5-2	2535		2256	1.44	4.65	100	675	2.15	9.90	121.1	

TABLE XVIII

Mix VI	Wt. Wet	Thickness when Formed	Wt. Dry	Thickness Dry	Breadth	Load in lbs.	Line Pressure	d^2	bd^2	Modulus of Rupture lbs. per sq. in.	Average
5-6-1	3858	2.54	3628	2.53	4.75	60	815	6.40	34.00	21.09	22.05
5-6-2	3887	2.56	3679	2.56	4.76	60	815	6.55	31.20	23.02	
6-6-1	3809	2.50	3574	2.48	4.75	70	815	6.15	29.20	28.80	30.60
6-6-2	3775	2.46	3537	2.46	4.75	78	815	6.05	28.78	32.50	
8-6-1	3824	2.43	3531	2.43	4.75	110	815	5.90	28.00	47.20	50.10
8-6-2	3757	2.39	3465	2.39	4.76	120	815	5.76	27.40	53.10	
9-6-1	3777	2.38	3447	2.36	4.75	150	815	5.51	26.20	68.00	69.70
9-6-2	3790	2.38	3465	2.36	4.76	155	815	5.51	26.25	70.80	
10-6-1	3744	2.35	3390	2.30	4.74	190	815	5.30	25.20	90.60	90.27
10-6-2	3767	2.35	3419	2.33	4.74	200	815	5.43	25.80	89.95	
12-6-1	3168	1.94	2818	1.89	4.73	160	815	3.57	16.85	114.10	110.50
12-6-2	3239	1.97	2885	1.95	4.74	160	815	3.80	18.05	107.00	
14-6-1	2803	1.77	2499	1.73	4.70	110	775	3.00	14.05	94.00	91.00
14-6-2	2576	1.59	2234	1.58	4.70	85	775	2.50	11.70	89.00	

the brick. The pressure application was at a rate of .08 inches per minute of verticle thrust. Two determinations were made of each mix and the average of the two taken as the result. These results are given in Tables 13-18 and shown graphically in Graph O.

DISCUSSION OF RESULTS

In the building brick mixes, the 100% Cheltenham mix with 8% water gave the most consistent porosity varying less than 1% over the entire block. The lower water contents gave widely varying results in both cases, as did the higher contents.

The 75% Missouri Flint and 25% Cheltenham mix with 8% water gave the best results among the fire brick mixes.

In general it can be said that the mixes with 8 and 9% water content gave the best results in all cases, while the higher water contents gave more variations.

Moisture contents of 7 to 8% have given the best results on both cases. As this is the amount used by practically all the manufacturers, it bears out the proof of the commercial practice.

In the building brick mixes, the 100% St. Louis Surface clay gave a much higher porosity in all cases than did the Cheltenham clay. This is no doubt due to the greater amount of colloidal material present in the St. Louis clay. All the fire brick mixes had porosities ranging between 18 and 23% with the exception of the 75% Missouri Flint and 25% Cheltenham, which had a higher range, it being from 26 to 30%. So it seems that the fire brick mixes are physically more alike than are the building brick clays. As these mixes are composed of more than one clay, it is possible that the proportios of each ingredient tend to equalize the other and so give an average figure for all the mixes. Thus it is shown that porosity is not affected so much by the amount of the ingredients of each mix as are other physical properties.

The maximum limit for water contents was 10 to 12% at which point the clays tended to flow thru the vents of the die. In only one case, that of the 75% Missouri Flint and 25% Cheltenham mix was it possible to get a block with 14% water, and then it was a poor specimen.

In taking the average porosities of each mix and plotting it against the amount of moisture, it is seen that the 75% Missouri Flint and 25% Cheltenham gave the best results, varying less than 1% over the entire moisture range. With the exception of the St. Louis

Surface Clay batch, all the other mixes showed an increase in porosity with an increase in water content. From this it may be assumed that the lubrication of the grains is not the essential factor in the distribution of pressure, other things being equal.

The final tests made on these mixes was the modulus of rupture tests on 1" brick. This dimension varied with the water contents and with the mixes, but was within close approximations of 1". This test showed the bonding power of the various mixes with the building brick mixes having the greatest, though one fire brick mix was within these values.

In the case of the St. Louis Surface Clay block, the modulus rose to a maximum at 8% water content and then dropped off rather rapidly, while the other building brick mix, 100% Cheltenham, decreased gradually from 5% to the maximum content of 12%. Its initial modulus was higher than that of the St. Louis Surface Clay but after 6% water content, the latter was always the greater.

Among the fire brick mixes, the 85.7% Cheltenham and 14.3% St. Louis Surface Clay gave the highest modulus but these varied greatly with the water contents. In this case, the strength rose rapidly at 6%, remained fairly constant to 9% and then dropped decidedly at 10%, when it was impossible to get a sample for a 12% mix due to the tendency of the clay to flow thru the die. The 92% North Missouri Flint and 8% grog mix gave the best results having fairly even strength thruout the entire water content range, showing a gradual increase with increase in water content.

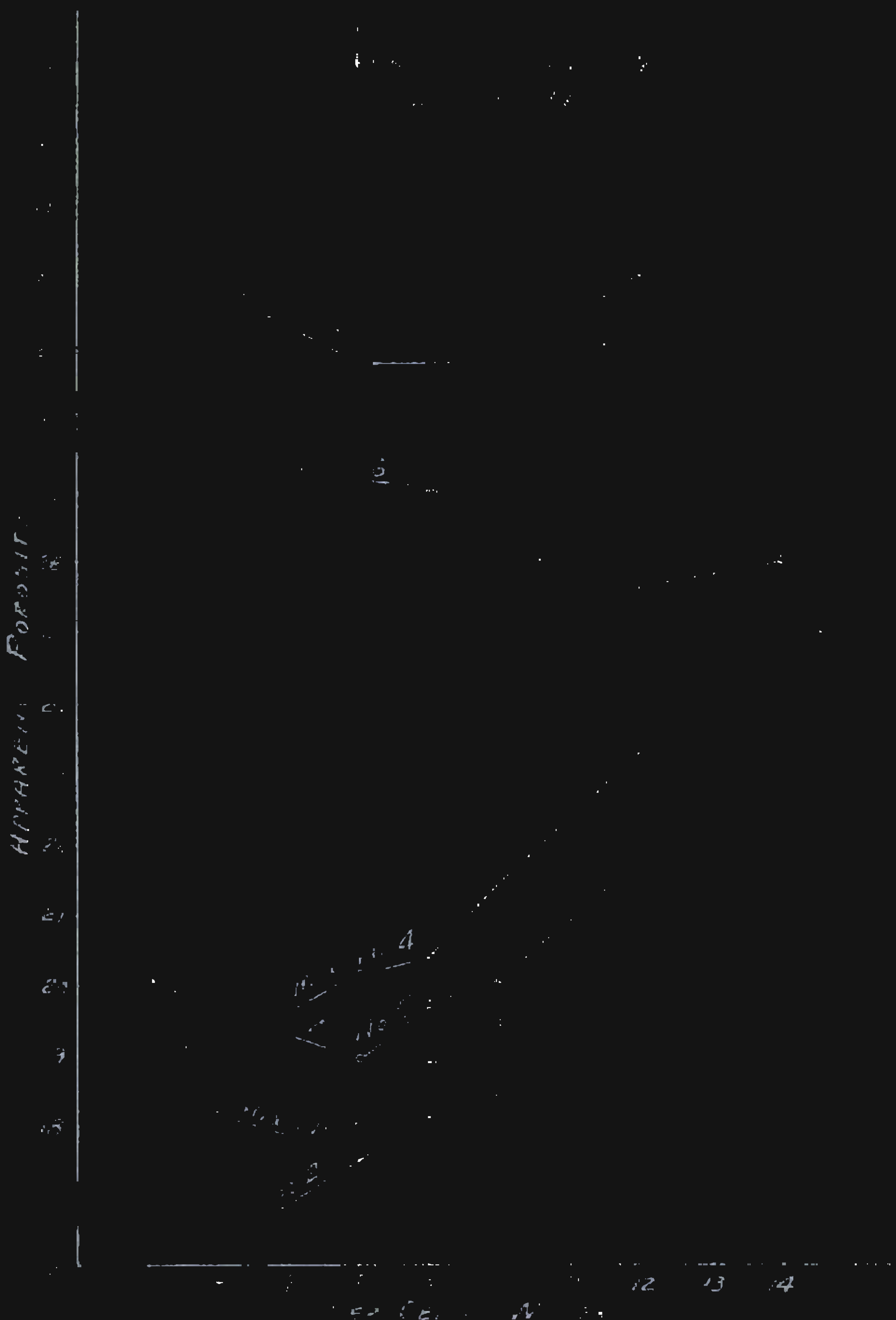
This investigation bears out the fact that the most practical water content for dry press at 2000 lbs. per sq. in. pressure is 7 to 8%, which is the one used in practice. In most cases, when 10% water content is reached, the clay tends to flow in the die and is unfit for dry press work. The higher water content did not tend to add to the bonding strength of the mixes and in some cases decreased this strength. Therefore, it seems that the water content is not a prime factor in the distribution of pressure, as the range is small and the results negative.

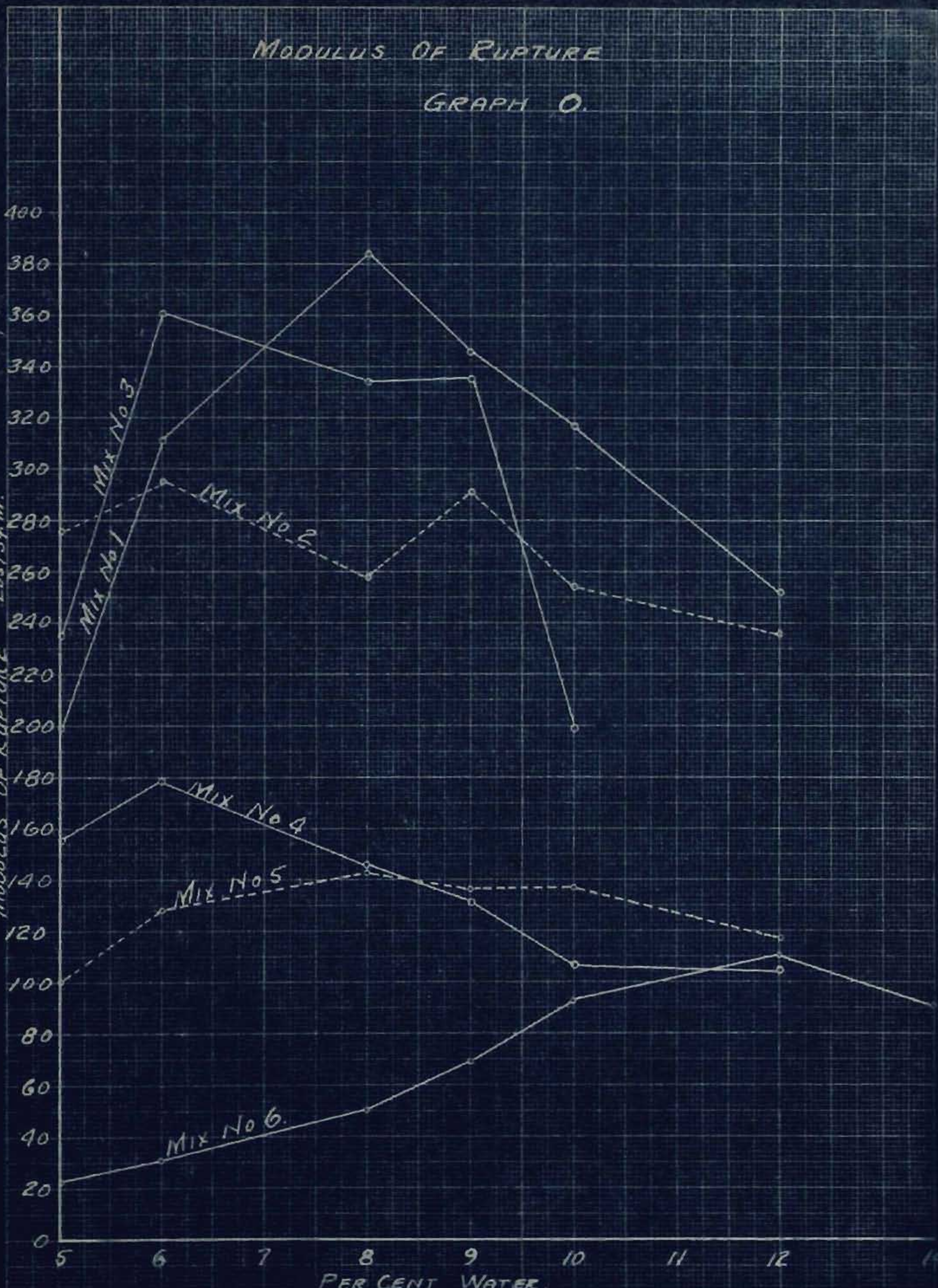
NOTE

This discussion was made very brief, due to the limited time in which to finish this report. All the data obtained in the investigations are given, however, and together with the graphs, it is possible to obtain conclusions relatively fast.

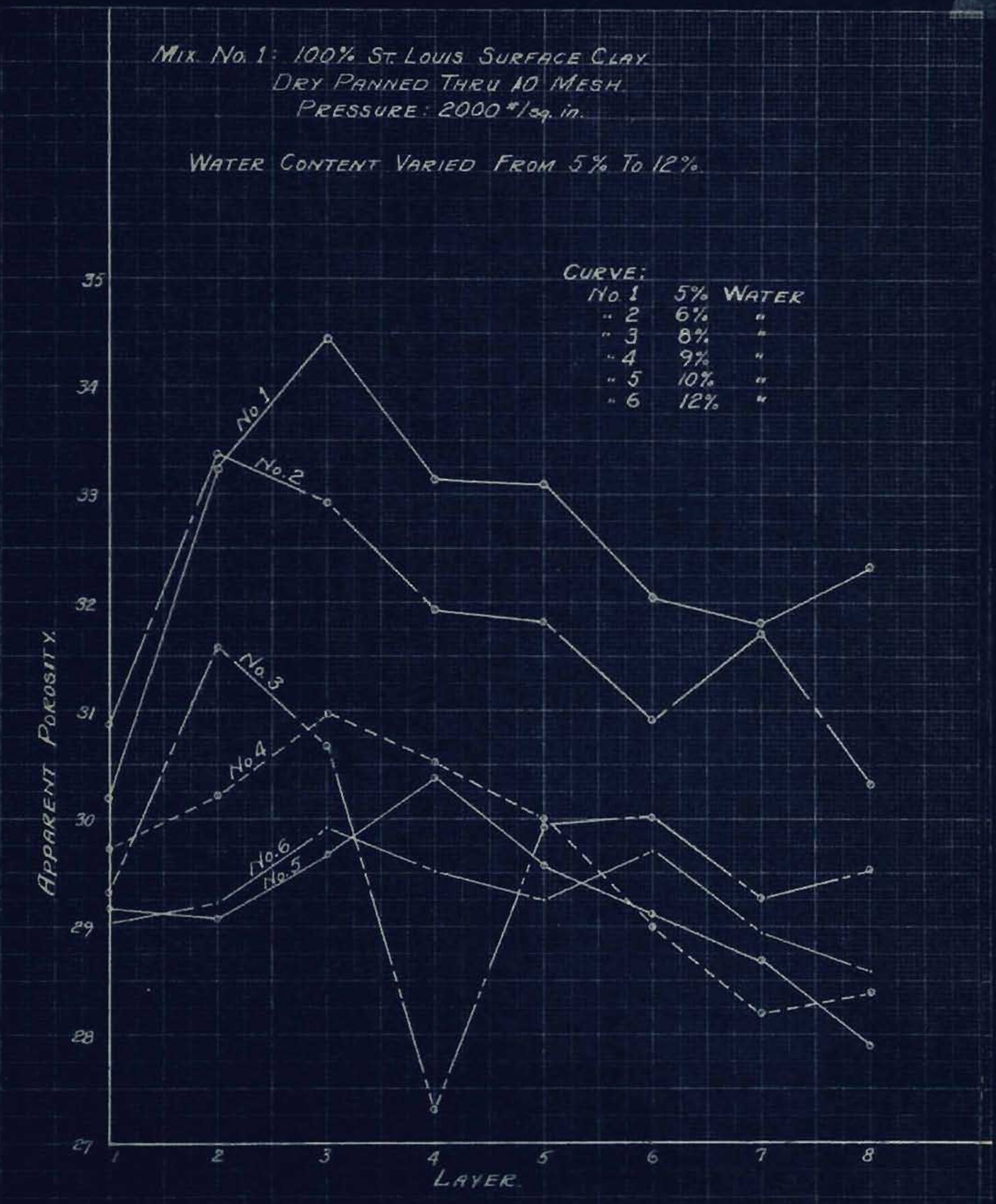
BULK SPECIFIC GRAVITY

GRAPH M

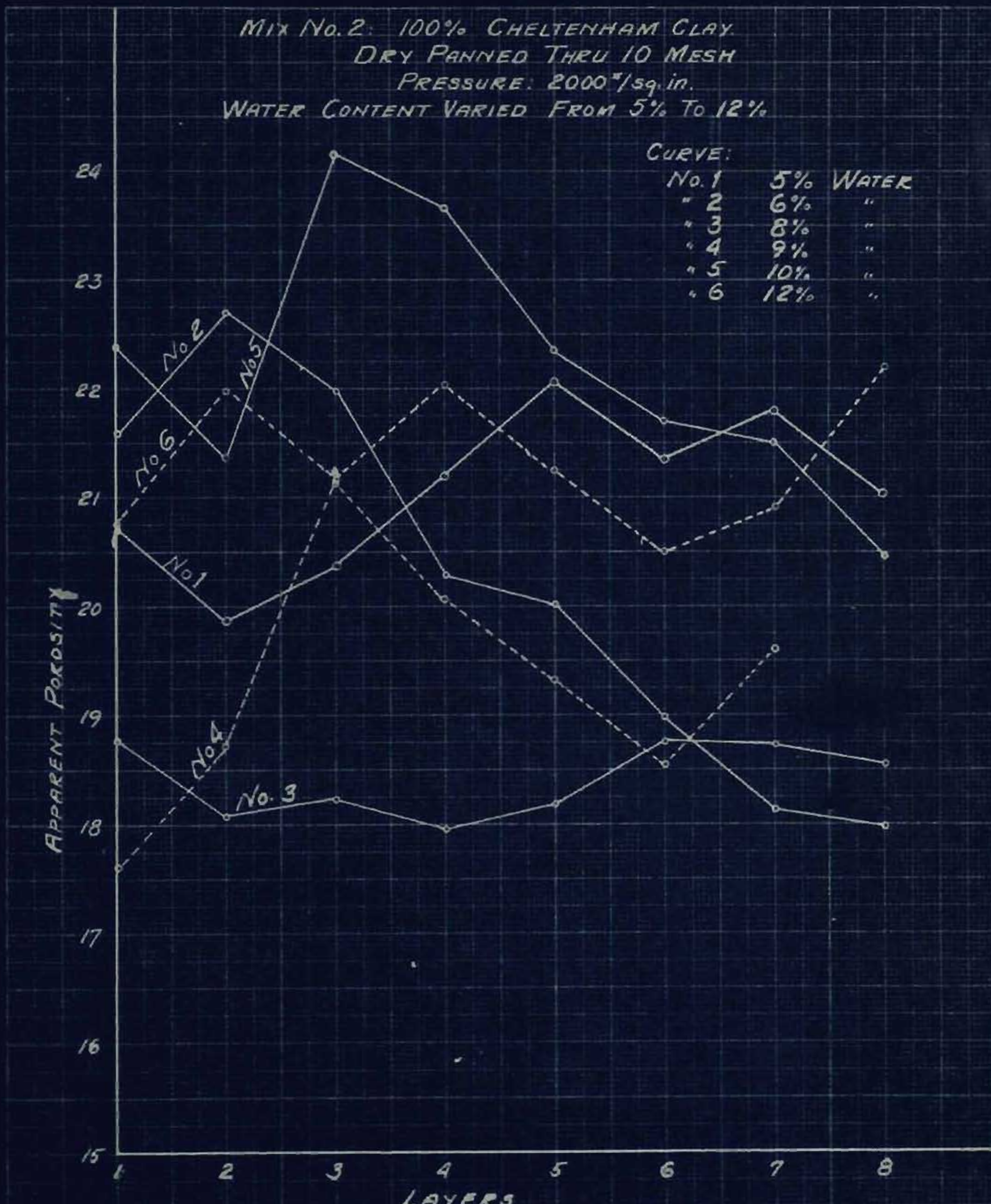




MODULUS OF RUPTURE
GRAPH O.
MODULUS OF RUPTURE Lbs/sq.in.
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
5
6
7
8
9
10
11
12
14
PER CENT WATER
Mix No 1
Mix No 2
Mix No 3
Mix No 4
Mix No 5
Mix No 6.


Mix No. 1: 100% St. Louis Surface Clay
Dry Panned Thru 10 Mesh
Pressure: 2000 #/sq. in.
Water Content Varied From 5% To 12%.
Curve:
No. 1 5% Water
" 2 6% "
" 3 8% "
" 4 9% "
" 5 10% "
" 6 12% "
No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
35
34
33
32
31
30
29
28
27
1
2
3
4
5
6
7
8
Apparent Porosity.
Layer.

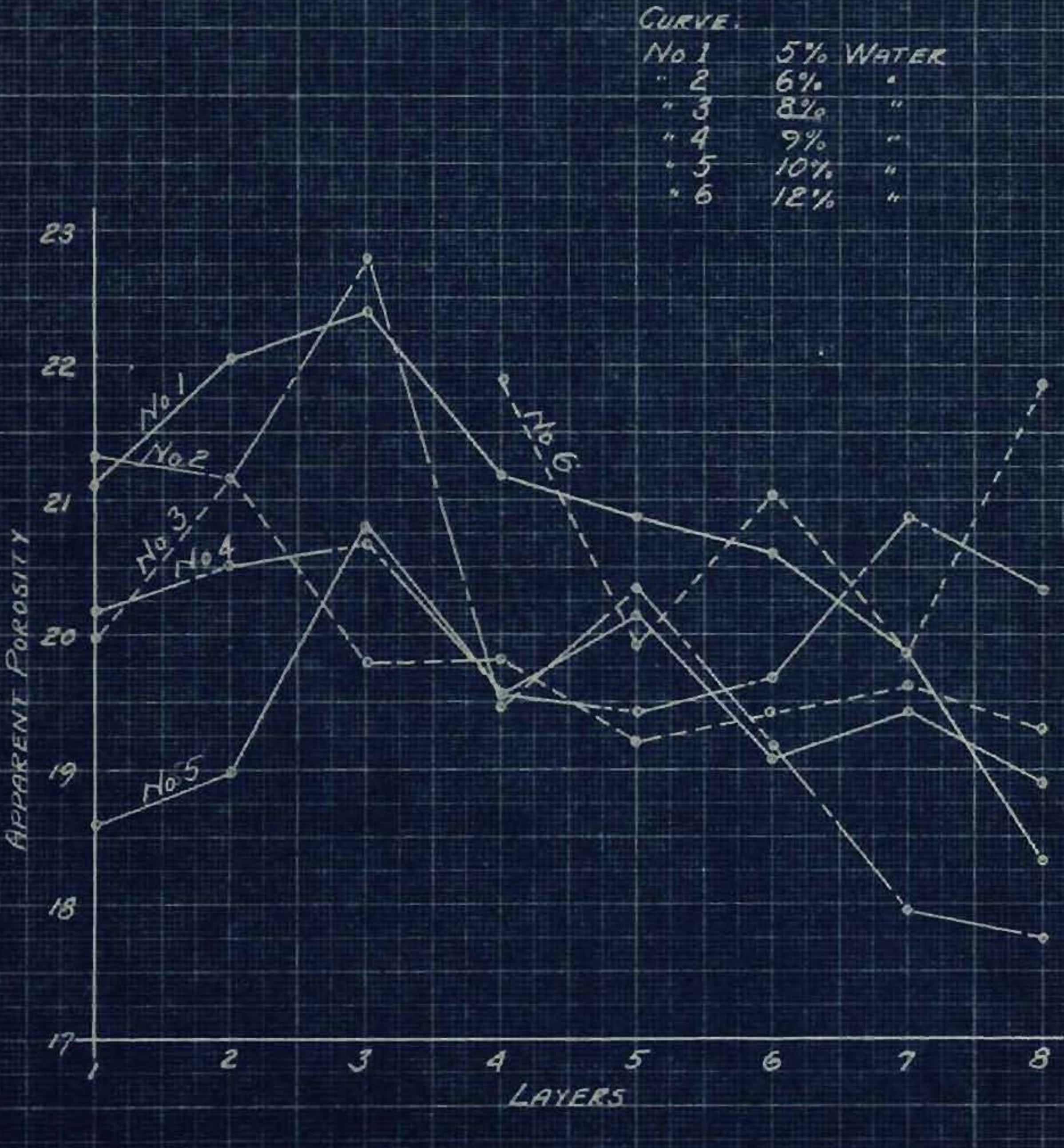
Graph P.


MIX NO. 2: 100% CHELTENHAM CLAY.
DRY PANNED THRU 10 MESH
PRESSURE: 2000#/sq. in.
WATER CONTENT VARIED FROM 5% TO 12%
CURVE:
No. 1 5% WATER
" 2 6% "
" 3 8% "
" 4 9% "
" 5 10% "
" 6 12% "
No 2
No 5
No 6
No 1
No 4
No. 3
APPARENT POROSITY %
24
23
22
21
20
19
18
17
16
15
1
2
3
4
5
6
7
8
LAYERS.

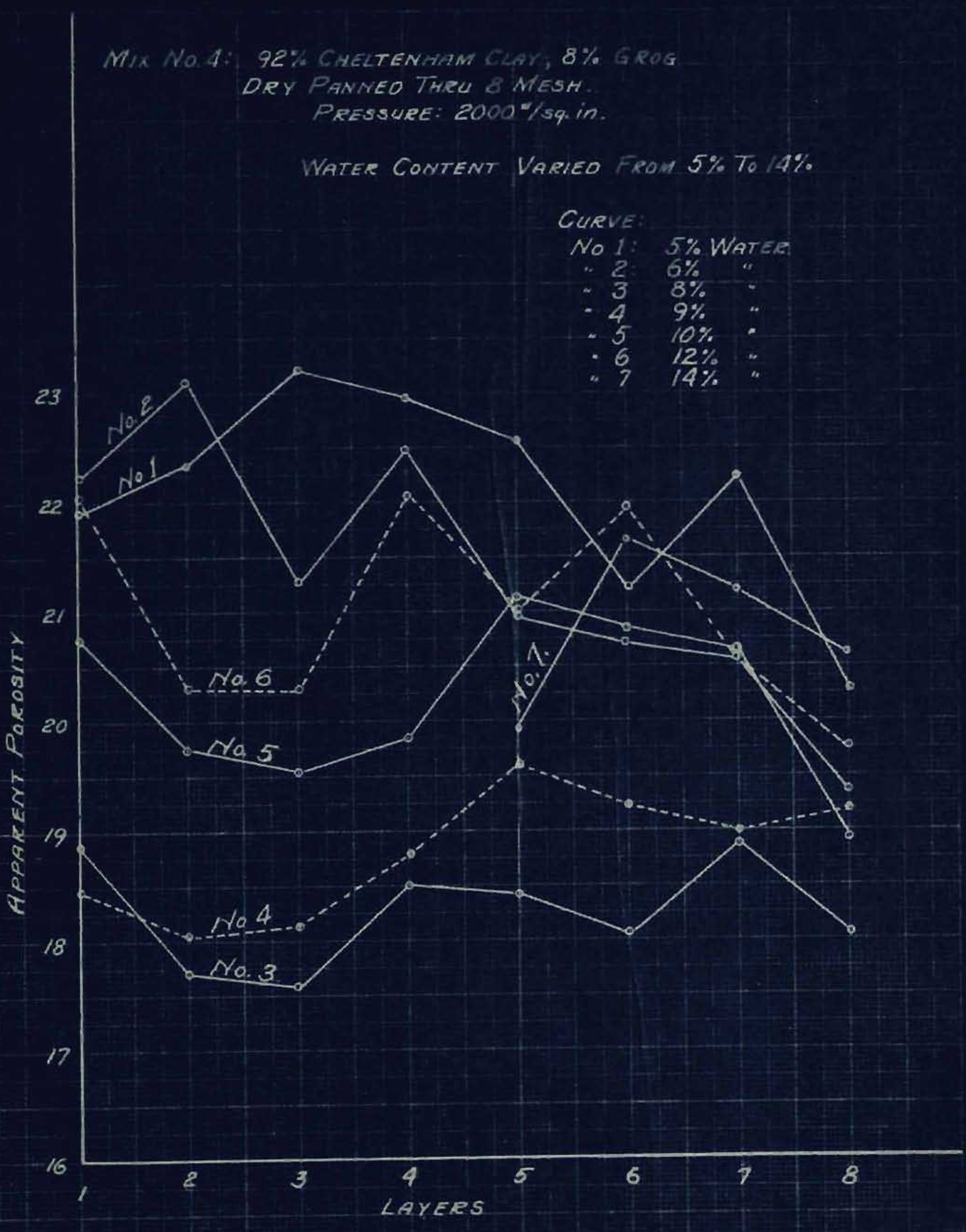
GRAPH Q

Mix No. 3: 6/7 Cheltenham Clay; 1/7 St Louis Surface Clay.
Dry Panned Thru 10 Mesh
Pressure: 2000#/sq in.

Water Content Varied From 5% To 12%

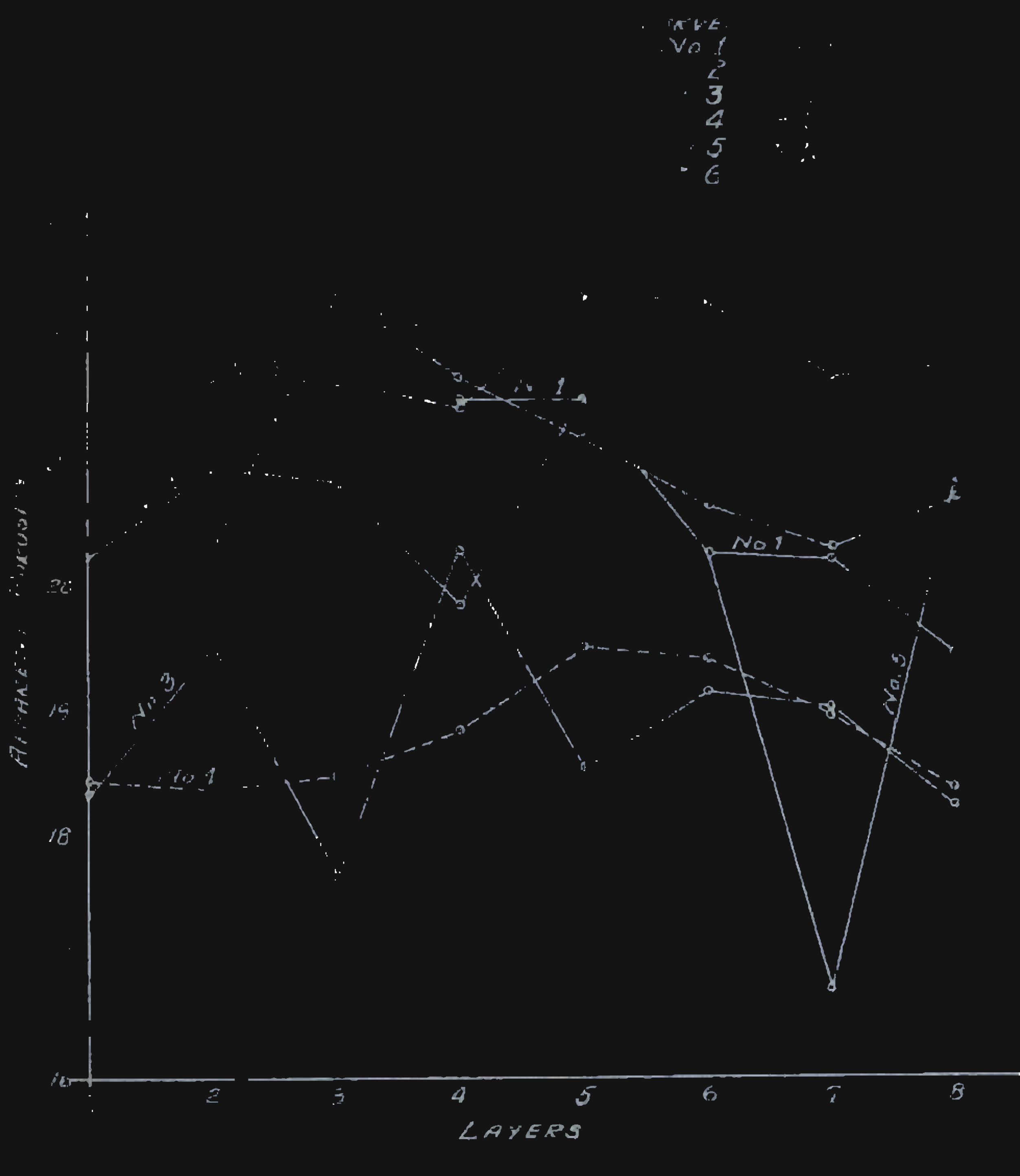


Graph R.



Mix No. 4: 92% Cheltenham Clay, 8% Grog
Dry Panned Thru 8 Mesh.
Pressure: 2000#/sq. in.
Water Content Varied From 5% To 14%.
Curve:
No 1: 5% Water
" 2: 6% "
" 3 8% "
" 4 9% "
" 5 10% "
" 6 12% "
" 7 14% "
No. 2
No 1
No. 6
No. 5
No. 7.
No 4
No. 3
Apparent Porosity
23
22
21
20
19
18
17
16
1
2
3
4
5
6
7
8
Layers

Graph 5



GRAPH T

MIX NO. 6: 75% MO. FLINT; 25% CHELTENHAM CLAY
DRY PANNED THRU 8 MESH
PRESSURE. 2000#/sq in

WATER CONTENT VARIED FROM 5% TO 14%

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