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The effect of various methods of grinding on the physical properties of unfired dry press brick

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THE EFFECT OF VARIOUS METHODS OF GRINDING ON THE PHYSICAL PROPERTIES OF UNFIRED DRY PRESS BRICK

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A

THESIS

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INTRODUCTION

In the manufacture of dry press brick, the final grinding of the clay is usually done in a dry pan. This is especially true of fire brick made by the dry press method.

It is logical to assume that different types of grinding machines will impart different characteristics to the ground clay mix, as regards the grain size variation and the shape of the grains, which in turn will have an effect on the properties of the brick.

The purpose of this investigation was to determine what effect different types of grinding methods have on the physical properties of unfired dry press brick.

METHOD OF INVESTIGATION

Five types of grinding machines were used.

1. Disintegrator--Squirrel cage type, 18" in diameter, with three sets of spindles revolving in opposite directions at 700 R.P.M.
2. Rolls--Sturtevant laboratory rolls, 6" in diameter, and set with 3/32" clearance.
3. Ball mill--Porcelain lined, 12" diameter, half charged with 2" diameter flint pebbles, and revolving at 40 R. P. M.
4. Wet pan--Convertible three foot wet and dry pan. Speed, 60 R.P.M.

In all cases the clay was first crushed down to a one inch maximum diameter with a jaw crusher. The final grinding of the clay by each method was done as outlined below. Where two clays or a clay and a grog were used in one mix, they were ground separately and later mixed in the required proportions in a mechanical mixer. One exception to this occurs in the wet pan method. In this method of grinding the final mix was ground together.

1. Disintegrator---The clay was run through the disintegrator and screened, using an 8 mesh screen for the fire brick mixes and a ten mesh screen for the face brick mixes. The same size screens were

used for all grinding methods. The tailings from the screen were run through the disintegrator again, and so on until all the clay had passed the required mesh.

2. Rolls---The clay was passed through the rolls set with a 3/32" opening, screened, and the tailings returned to the rolls until all the clay passed through the required mesh.

3. Dry pan---Same as (1), using the dry pan in place of the disintegrator.

4. Ball mill---In this method the clay was ground in the ball mill and screened through the desired mesh at about five minute intervals, until it all passed through the screen.

5. Wet pan---The clay mix in the proper proportions was ground dry in the pan for eight minutes. The required amount of water was then added and the mix ground an additional four minutes. The pan was then emptied and the tempered mix placed in a covered container to age for twenty-four hours before making up the brick.

The total moisture contents of the other mixes was brought up to seven percent by sprinkling the necessary amount of water on the clay and mixing it in a mechanical mixer until all lumps had disappeared. Each mix, after tempering, was aged twenty-four hours in a covered container before making up the brick.

The proper amount of moisture in the mix to make the best brick, varied, of course, with the type of clay used. However, since only comparative data between various grinding methods was desired, the proper moisture content had little significance as long as it was the same for each mix. Seven percent was used as a standard for all mixes.

A hydralic press with the following specifications was used in making the brick. Total pressure obtainable equivalent to 6000# per sq. inch; mold box dimensions, 20"x9$\frac{3}{4}$"x4$\frac{3}{4}$"; lower ram travel, 22 inches; mold box travel, 1$\frac{1}{4}$"; a gauge in the compression line between the press proper and the electric plunger pump indicates the pressure at all times. By manipulating the valves the desired pressure may be reached and held for any length of time.

A small scoop was used to fill the mold box to prevent grain segregation. A standard weighed amount of the tempered mix was used for each brick.

A pressure of two thousand pounds per sq. inch applied for two seconds was used in making all the brick. Ten similar brick were made up in each case, and each result given in Table 1 is the average of data obtained on ten brick.

The brick were dried at room temperatures for two weeks, then placed in a drier and dried for forty-eight hours at 225 degrees Fahr. After cooling to room temperatures, they were measured to obtain the linear drying shrinkage and then broken with a Riehle cross-breaking machine. The transvere breaking strength was calculated to and reported in terms of modulus of rupture.

The broken brick were weighed dry, submerged in kerosene in a vaccum tank, and subjected to a 23" vaccum for three hours. They were then removed, the excess kerosene wiped off with a cloth dampened with kerosene, and weighed both in air and suspended in kerosene.

The physical properties of the dry brick, calculated from the data obtained in the above procedure, were as follows:

1. Modulus of rupture, pounds per sq. inch.
2. Bulk density.
3. Percent apparent porosity.
4. Percent linear drying shrinkage.

These are the most important properties which are affected by grinding, and form a good basis for comparision between different brick.

Five separate mixes, each of which is used in making brick commercially, representing a fairly wide variety of face brick and fire brick, were used. Fifty brick were made up of each mix, ten brick representing one grinding method for each mix.

A short description of each mix is given below.

Mix A--84.7% Cheltenham fire clay, 14.3% St. Louis surface clay.

Mix B--100% St. Louis surface clay, which is a red-burning loess clay.

Mix C--92% North Missouri semi-flint clay, 8% fire clay grog.

Mix D--92% Cheltenham fire clay, 8% fire clay grog.

Mix E--75% Hard Missouri No. 1 flint clay, 25% Cheltenham fire clay.

A screen analysis, using Standard Tyler Sieves, was made of the mix for each lot of brick.

SUMMARY OF DATA

TABLE NO.1

MIX A

Method of grinding	Mod. of rupture	Bulk density	% App. porosity	% Lin.Dry. shrinkage	Depth of brick
Dry pan	278.9	2.165	17.08	.724	2.58"
Ball mill	311.7	2.179	17.22	.724	2.59
Rolls	215.9	2.152	18.32	.618	2.60
Disintegrator	101.2	2.036	21.40	.309	2.69
Wet pan	379.5	2.189	14.34	.724	2.56

MIX B

Method of grinding	Mod. of rupture	Bulk density	% App. porosity	% Lin.Dry. shrinkage	Depth of brick
Dry pan	250.4	1.846	30.44	.309	2.58"
Ball mill	266.9	1.834	30.76	.309	2.60
Rolls	257.2	1.846	30.34	.309	2.57
Disintegrator	240.6	1.828	31.14	.309	2.58
Wet pan	324.4	1.847	30.55	.309	2.57

MIX C

Method of grinding	Mod. of rupture	Bulk density	% App. porosity	% Lin. Dry. shrinkage	Depth of brick
Dry pan	108.7	2.110	19.33	.206	2.65"
Ball mill	94.2	2.129	18.83	.309	2.66
Rolls	112.4	2.110	19.32	.206	2.65
Disintegrator	103.2	2.112	19.94	.206	2.63
Wet pan	123.2	2.112	20.51	.309	2.66

MIX D

Method of grinding	Mod. of rupture	Bulk density	% App. porosity	% Lin.Dry shrinkage	Depth of brick
Dry pan	65.8	2.092	21.26	.206	2.65"
Ball mill	102.0	2.086	21.16	.309	2.67
Rolls	80.3	2.095	20.95	.309	2.65
Disintegrator	97.4	2.114	19.97	.206	2.64
Wet pan	138.5	2.125	15.67	.412	2.63

MIX E

Method of grinding	Mod. of rupture	Bulk density	% App. porosity	% Lin.Dry shrinkage	Depth of brick
Dry pan	20.2	1.899	27.04	.00	2.92
Ball mill	27.5	1.923	27.14	.00	2.87
Rolls	16.9	1.885	27.94	.00	2.94
Disintegrator	23.8	1.881	28.39	.00	2.96
Wet pan	54.9	1.936	25.16	.00	2.89

NOTE--10# of clay per brick in A,C,D, and E.
8# " " " " B

TABLE NO.2

MIX A

	Dry pan	Wet pan	Ball mill	Rolls	Disintegrator
On 14 mesh	17.37	7.28	18.40	25.74	17.49
14-20	9.59	8.02	9.26	13.33	14.59
20-28	10.80	11.80	9.73	13.50	17.28
28-35	7.61	10.67	6.63	8.38	12.19
35-48	5.91	10.14	5.33	6.17	8.81
48-65	4.94	9.06	4.76	4.81	6.19
65-100	6.84	12.81	8.50	6.06	6.10
100-150	8.59	10.14	13.01	5.88	4.48
150-200	3.84	3.22	3.67	1.80	1.39
Thru 200	24.53	16.81	20.70	14.14	11.48
	100.02	99.95	99.99	99.81	100.01

MIX B

	Dry pan	Wet pan	Ball mill	Rolls	Disintegrator
On 14 mesh	11.33	3.78	4.25	15.39	10.82
14-20	8.87	5.88	2.77	11.47	8.61
20-28	10.48	10.90	3.98	12.97	11.80
28-35	7.32	9.16	3.05	7.57	8.43
35-48	5.40	6.86	2.57	5.06	6.46
48-65	3.84	4.88	2.55	3.70	4.40
65-100	3.39	4.71	3.26	3.15	4.53
100-150	2.37	4.00	2.90	2.29	3.58
150-200	1.04	1.97	1.36	.99	1.26
Thru 200	46.00	47.82	73.23	37.26	40.08
	100.04	99.96	99.92	100.05	99.97

MIX C

	Dry pan	Wet pan	Ball mill	Rolls	Disintegrator
On 10 mesh	10.73	7.89	15.38	28.56	16.80
10-14	11.58	8.13	15.61	22.27	16.70
14-20	9.24	7.45	11.19	11.77	13.14
20-28	11.57	11.13	11.87	11.17	14.99
28-35	8.90	9.23	8.18	6.47	10.12
35-48	7.49	8.87	6.38	4.44	7.27
48-65	6.61	7.64	5.37	3.35	4.93
65-100	10.42	10.28	9.08	3.30	5.22
100-150	8.12	7.99	5.41	2.79	3.86
150-200	2.42	2.84	3.85	.85	.98
Thru 200	12.95	18.57	7.71	5.15	6.02
	100.03	100.04	100.03	100.12	100.03

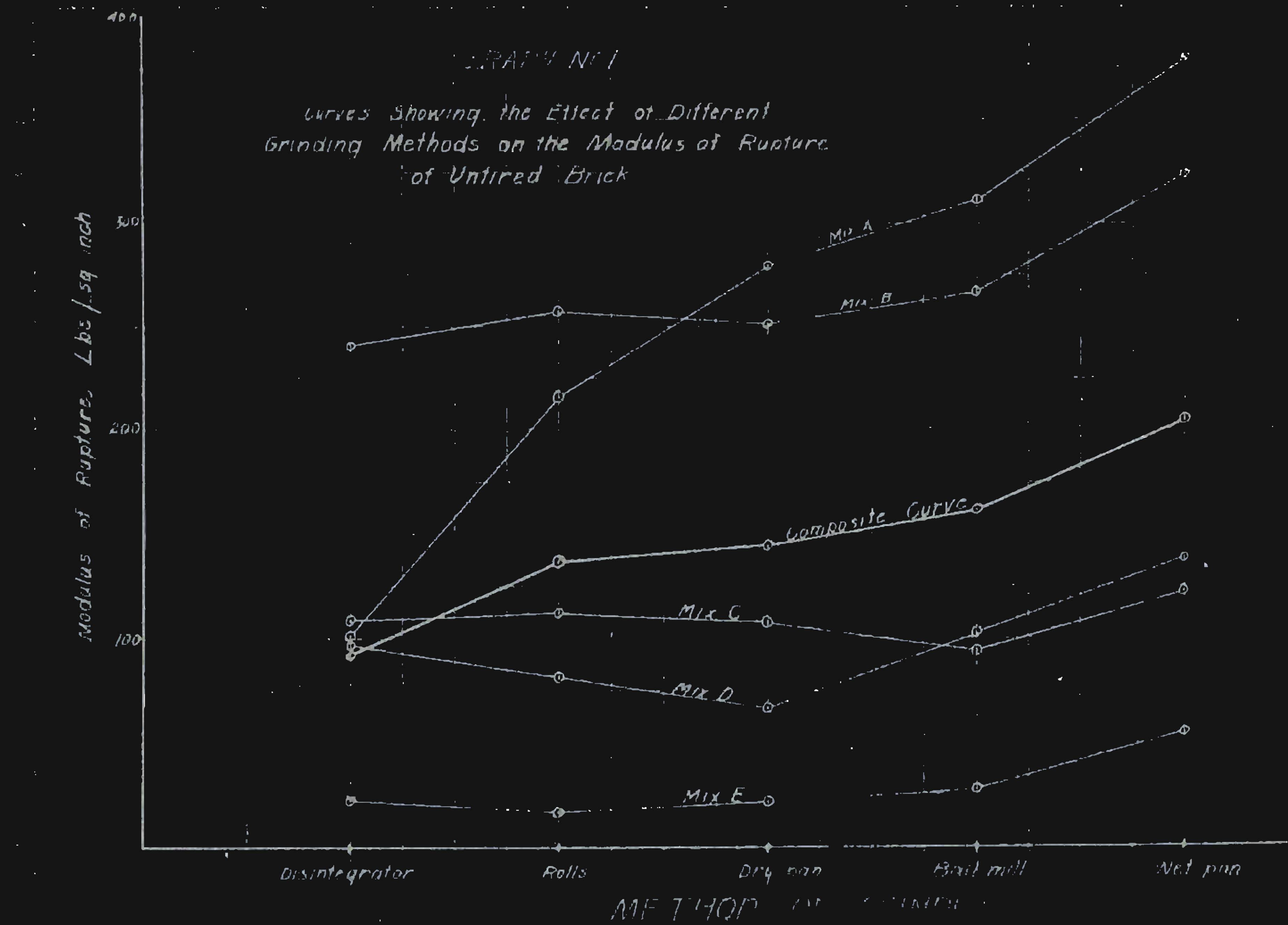
TABLE NO. 2 (CONTINUED)

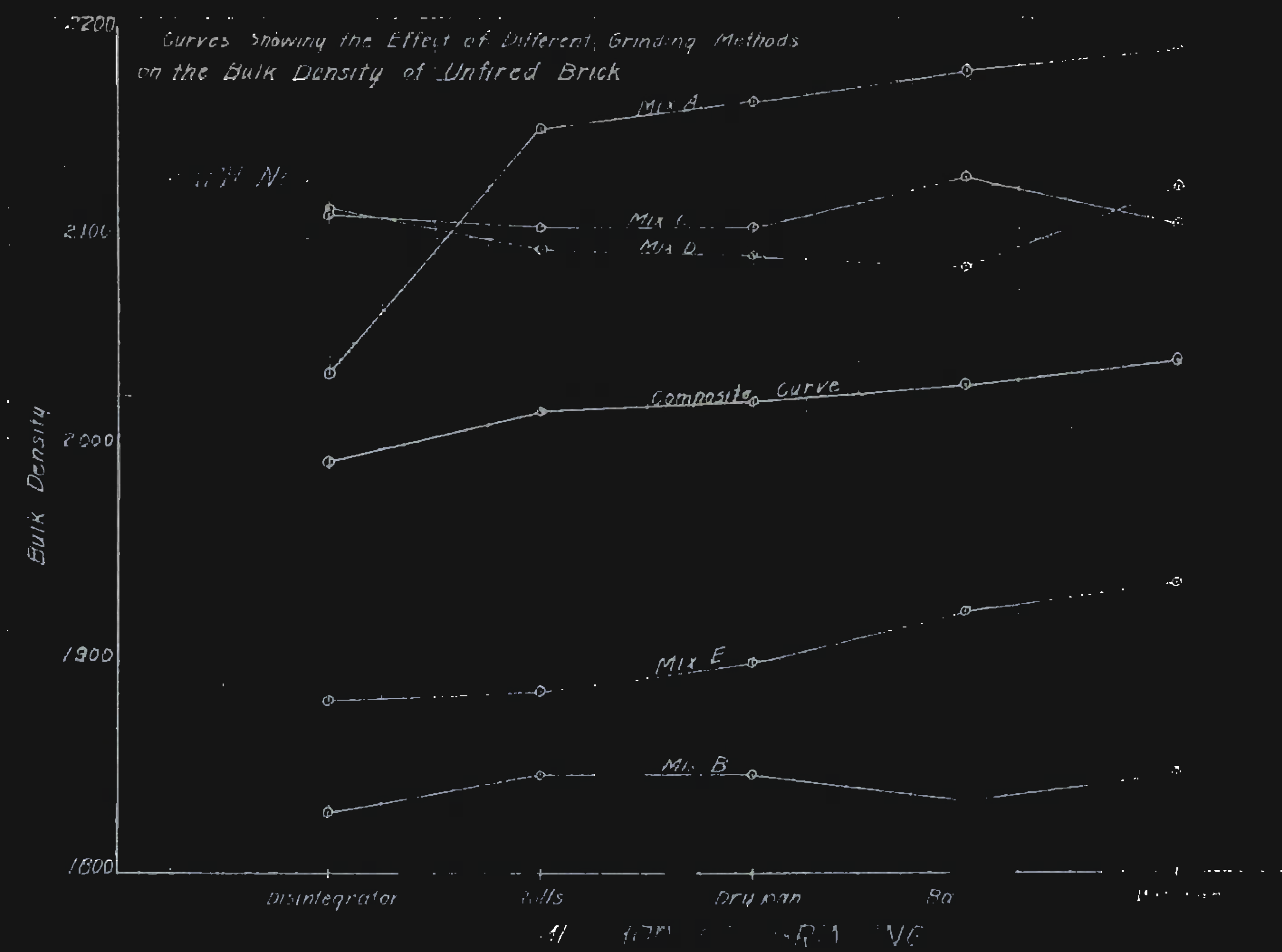
MIX D

	Dry pan	Wet pan	Ball mill	Rolls	Disintegrator
On 10 mesh	6.61	2.41	16.78	19.51	18.92
10-14	14.58	6.51	12.90	16.53	19.40
14-20	11.49	8.01	9.19	11.96	13.58
20-28	13.20	12.18	10.71	13.17	14.69
28-35	9.77	10.91	7.74	8.97	9.55
35-48	8.02	10.45	6.36	6.91	6.40
48-65	6.75	9.09	5.46	5.22	4.42
65-100	9.96	10.62	8.36	5.32	4.19
100-150	6.94	8.66	9.49	4.24	2.96
150-200	2.80	2.88	4.97	1.33	.79
Thru 200	9.89	18.27	7.69	6.83	5.09
	100.01	99.99	99.95	99.99	99.99

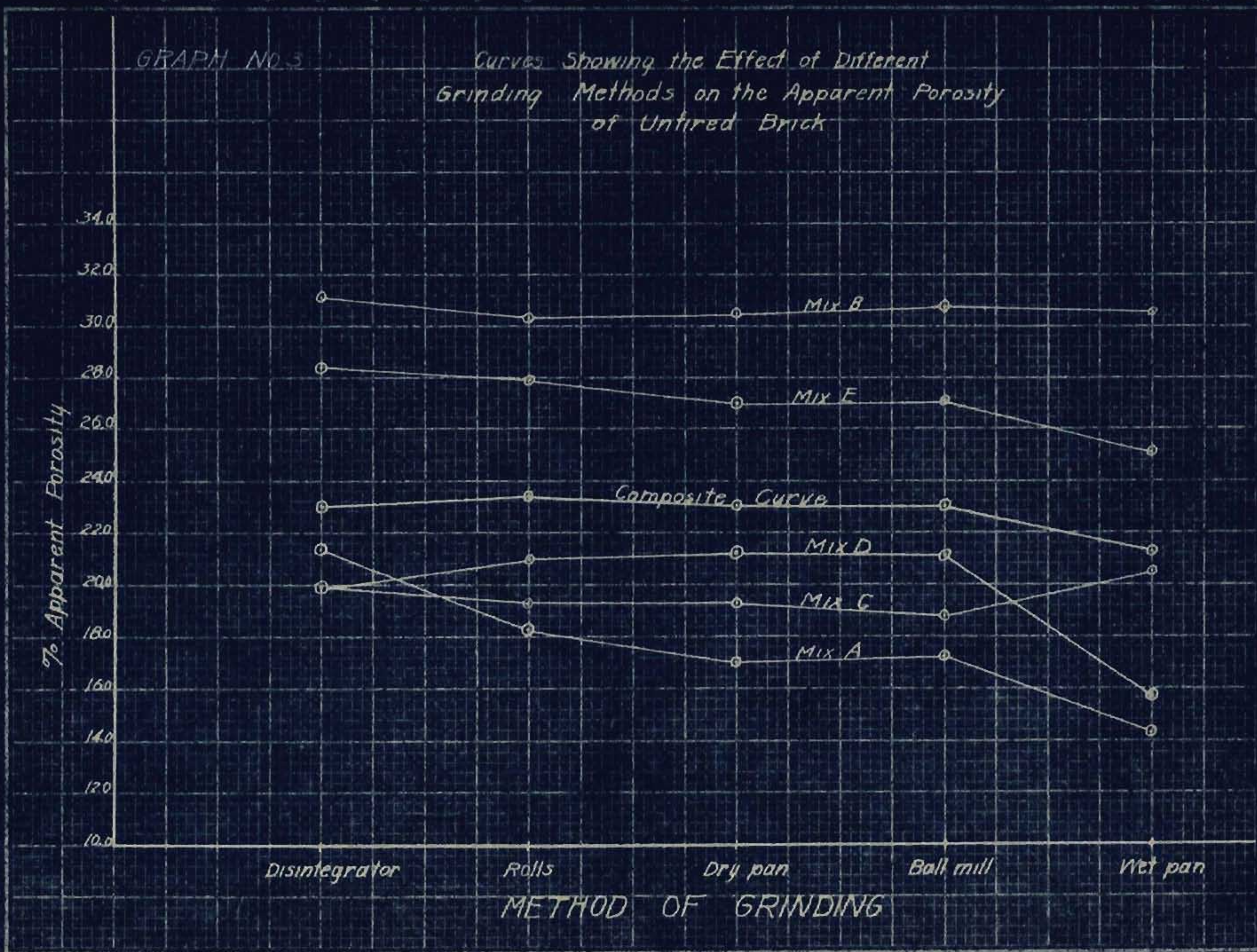
MIX E

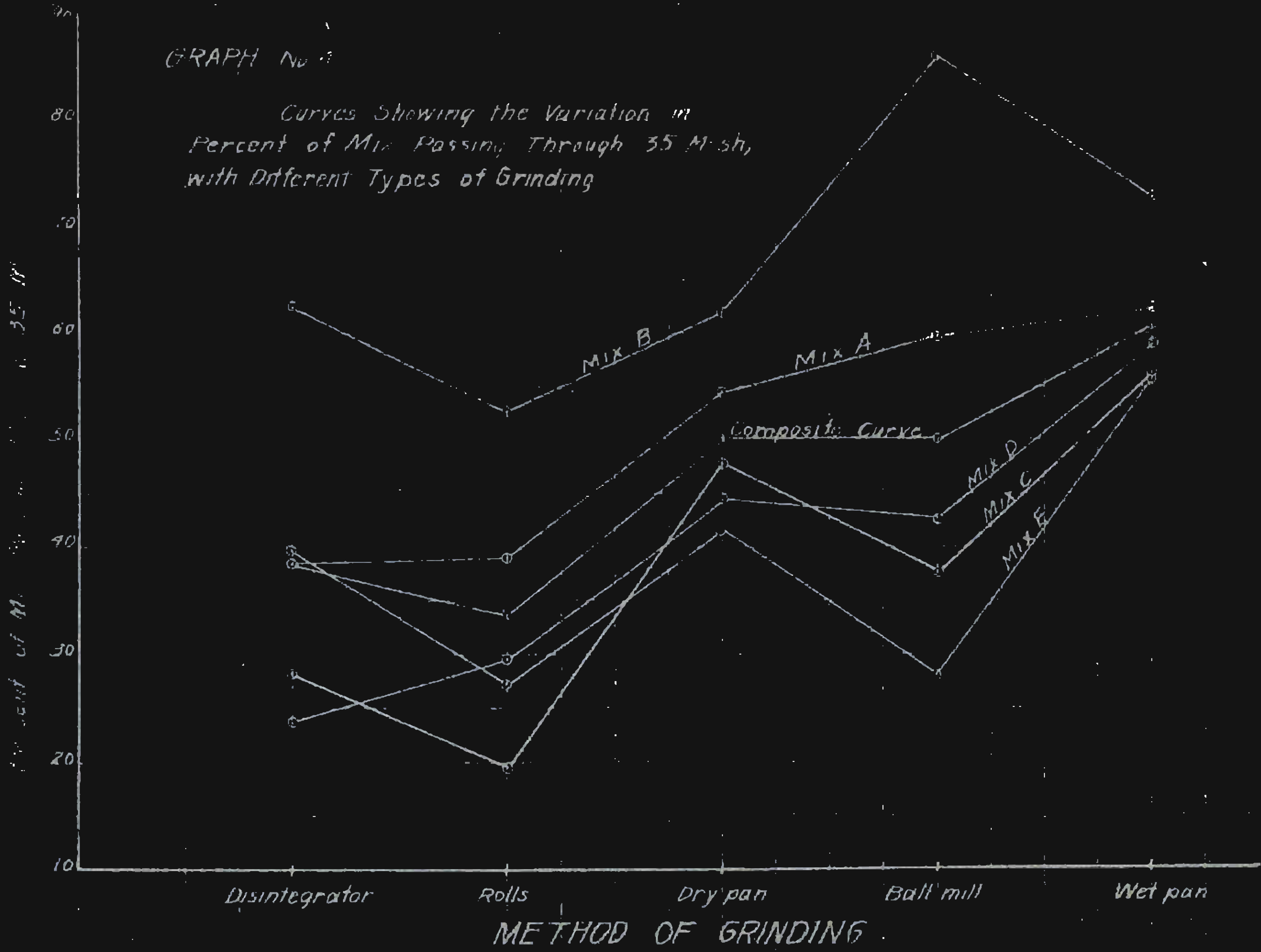
	Dry pan	Wet pan	Ball mill	Rolls	Disintegrator
On 10 mesh	13.40	7.63	21.34	22.15	6.55
10-14	13.04	8.30	17.78	18.28	12.69
14-20	10.10	7.65	11.93	11.68	12.04
20-28	12.40	11.00	12.58	12.34	16.28
28-35	9.61	9.41	8.36	8.25	12.63
35-48	8.43	9.39	6.37	6.32	10.22
48-65	8.37	11.37	5.01	5.06	7.93
65-100	9.83	10.85	6.23	5.33	8.83
100-150	7.21	13.24	3.97	4.46	7.65
150-200	2.29	4.06	1.25	1.30	.92
Thru 200	5.30	7.02	5.07	4.85	4.22
	99.98	99.92	99.89	100.02	99.92


GRAPH No. 1
Curves Showing the Effect of Different Grinding Methods on the Modulus of Rupture of Unfired Brick
400
300
200
100
Modulus of Rupture, Lbs./sq. inch
Mix A
Mix B
Composite Curve
Mix C
Mix D
Mix E
Disintegrator
Rolls
Dry pan
Ball mill
Wet pan
METHOD



Curves Showing the Effect of Different Grinding Methods
on the Bulk Density of Unfired Brick
Mix A
Mix C
Mix D
Composite Curve
Mix E
Mix B
Bulk Density
2200
2100
2000
1900
1800
Disintegrator
Rolls
Dry pan


GRAPH NO. 3
Curves Showing the Effect of Different
Grinding Methods on the Apparent Porosity
of Unfired Brick
% Apparent Porosity
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
Mix B
Mix E
Composite Curve
Mix D
Mix C
Mix A
Disintegrator
Rolls
Dry pan
Ball mill
Wet pan
METHOD OF GRINDING



GRAPH No
Curves Showing the Variation in
Percent of Mix Passing Through 35 Mesh,
with Different Types of Grinding
Mix B
Mix A
Composite Curve
Mix D
Mix C
Mix E
80
60
50
40
30
20
10
Disintegrator
Rolls
Dry pan
Ball mill
Wet pan
METHOD OF GRINDING

DISCUSSION OF THE RESULTS

In Table 1 are given the physical properties of each lot of brick. Each one of the five mixes used was prepared by the five milling methods indicated and previously outlined. Graphs No's 1,2, and 3, are plotted from the data given in Table 1, and show the relative effect of the various grinding methods on the physical properties of the brick from each mix.

Referring to Graph No. 1, it is obvious that the method of grinding does not have the same relative effect in each mix in regard to the strength of the brick. In all mixes the wet pan method gives the strongest brick. Taking average values, as shown by the curve which is a composite of the other curves, the ball mill method gives the next strongest brick, followed by the dry pan, rolls, and disintegrator, in the order given. With the exception of Mix A, which shows a very large variation in strength with all the different grinding methods, the values of the modulus of rupture vary but little with the type of grinding, except for the wet pan method.

It is interesting to note that in Mixes A and B, which are face brick mixes, the disintegrator gives the weakest brick, while in the other mixes, which are fire brick mixes, the disintegrator method produces brick practically equal to, and in some cases stronger than those made by all other methods except wet-panning.

The effect of the grinding method on the bulk density of the brick is shown in Graph No. 2. Referring to average values, the bulk density increases among the various grinding methods in the same order as the modulus of rupture. Considering individual mixes, however, there is some variation. The wet pan method gives the highest bulk density in all mixes except Mix C, in which it produced by the ball mill method. Mix A shows a greater variation in bulk density with type of grinding than any of the other mixes. This mix showed the greatest variation in strength also, and the same is true of its other properties. The method of grinding used for this mix is, therefore, of considerable significance.

Since it is a face brick mix, high strength and low porosity are desirable properties. Graph No. 3 shows that the apparent porosity of these brick milled by the wet pan method is the lowest of any brick made. Consequently, the wet pan method of grinding for this mix produces the best brick by a large margin.

In fire brick the properties desired vary with the use for which the brick is intended. For best resistance to abrasion and slag action a brick with low porosity, high density, and high strength is desirable. The wet pan method of grinding is for practically all mixes the best method for making this type of brick.

For high resistance to spalling, an open body is necessary. The wet pan method generally does not impart this property. In most mixes the disintegrator method gives the the highest porosity, but in mixes D, and C, the highest porosity is produced by the dry pan and wet pan methods respectively. It is interesting to note that the strength of some mixes may be increased considerably by changing the grinding method, without changing the porosity of the brick.

No curves were drawn to show the effect of the method of grinding on the linear drying shrinkage of the brick because the shrinkage was very small in all mixes. It was so small that 1/100" wear in the mold box would cause an appreciable error in the result, and between the time the first and the last brick were made up, an actual increase in size to this extent took place. The trend in drying shrinkage for the various types of grinding generally runs parallel to the strength of the brick, the stronger brick giving the highest shrinkage, and vice versa. The highest shrinkage for any mix was less than one percent, and this occurred in Mix A. In Mix E, containing 75 percent flint clay, there was no shrinkage in drying.

Table No.2 gives the screen analysis of the mixes for each lot of brick made up. To show more clearly the relative effect of the grinding method in producing a certain percentage of fines, in Graph No.4, the method of grinding was plotted against the the percent of each mix passing through 35 mesh. Generally the wet pan method produced the largest percentage of fines, although in Mix B, it was higher in the ball mill mix. The rolls generally produced the coarsest mix with the disintegrator next. In the face brick mixes the ball mill method produced a higher percentage of fines than the dry pan, while in the fire brick mixes it was the other way around.

Typical screen analyses of Missouri fire brick mixes, given J.H.Kruson and C.A.Smith[1] are quite similar to the screen analyses of the fire brick mixes used here, that were ground by the rolls and the disintegrator. The wet pan, dry pan, and to some extent the ball mill method, give a much higher percentage of material through 48 mesh.

The high strength of the brick made by the wet pan method is due perhaps to some extent to the high percentage of fines in these mixes. However, it cannot be attributed entirely to this, for in Mix B the highest strength is given by the wet pan method while the ball mill method gives the highest percentage of fines. The high strength to the brick, milled by the wet pan method, is quite likely due partly to the higher percentage of fines in the mix, and partly to the characteristic feature of the wet pan of producing excellent tempering in a clay mix.

[1] Jour. Amer. Cer. Society, Vol. 8, page 829 (1925)

CONCLUSIONS

It is apparent from the data that the choice of the method of milling to be used, to obtain the best brick, depends largely on the kind or kinds of clay making up the mix and the properties desired in the brick. The value of the data obtained in this investigation lies not so much in the general conclusions that can be drawn from them as in the specific information in regard to each mix.

It is suggested that manufacturers of dry press face brick and fire brick compare the mixes used in this work with their own, and the data presented should be of value to them in their choice of the method of milling which will give them the best results.

RECOMMENDATIONS

It was originally intended to include in this work, a shape analysis of the grains of each mix, dividing them into three fractions, chunky grains, flaky grains, and elongated grains, and obtaining the percent by weight of each fraction. This analysis would perhaps give interesting information as to why different milling methods produce different properties in the brick.

In furthering the work done in this investigation, the next logical step would be to obtain the variation with method of grinding of the physical properties of the fired brick.

ACKNOWLEDGEMENTS

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