Chemical & Physical Properties Of Vitrified Bricks

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A Comparison of the

CHEMICAL and PHYSICAL PROPERTIES

of

Vitrified Bricks.

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COMPARISON OF THE CHEMICAL AND PHYSICAL PROPERTIES OF VITRIFIED BRICKS.

The striking increase in the use of vitrified bricks for paving purposes, has caused the industry to become one of utmost importance. Paving brick are rapidily replacing asphalt and even granite on streets where heavy teaming occurs. Although the use of paving brick is very extensive, it began at a comparatively recent date, and the standardizing and developing of the various tests is, even yet, in an unsatisfactory condition, so that the quality of the brick is not always determined by the tests put upon it. The chemical analysis of brick has, heretofore, had little to do to control the quality of the product obtained, manufacturers simply using the raw material as it was mined.

The aim of this thesis is to attempt to establish some relation between the chemical and physical properties of vitrified brick; to try to show what effects different amounts of any substance, as shown by the chemical analysis, have upon the quality of the brick as determined by the standard physical tests. While we were unable to compare, in this manner, as many different kinds of brick as we wished, still we feel that the conclusions we have drawn at the end of this paper are general enough to include all vitrified brick.

METHODS OF CHEMICAL ANALYSIS.

Duplicate analysis were made of all samples.

PREPARATION OF THE SAMPLE.

A sample was taken from various portions of several bricks of each kind, and crushed in a Buck mortar to the size of a pea, and quartered in the usual manner. The final portion was then crushed so as to pass through a 100 mesh U. S. standard sieve.

TREATMENT WITH FUSION MIXTURE.

A one gram sample was accurately weighed, and mixed with about ten grams of fusion mizture (K_2CO_3 and Na_2CO_3 mixed in molecular proportions with the addition of a little KNO_3), in a 25 gram platinum crucible. Heated the open crucible carefully and slowly until the contents was completely fused. When fused the crucible was heated in a blast at a high temperature for about fifteen minutes, care being taken that none of the brick adhered to the side of the crucible, and so remained unfused. The crucible was allowed to cool rapidily so as to loosen the cake. When cold the cake and crucible were placed in a five inch evaporating dish, and digested with water and HCl until all the mass was entirely disintegrated, and the excess of carbonates expelled. The crucible was then removed and all the adhering matter washed into the dish.

DETERMINATION OF SILICA.

The mass was then evaporated to dryness on a hot plate, and at the end of the operation was stirred continually with a glass rod to prevent spattering. When nearly dry it was moistened with HCl, and evaporated to dryness again; this time to complete dryness and baked. Cooled, moistened with concentrated HCl and heated on a water bath for about an hour. Added some hot water decanted through a filter, washed the same way, and finally filtered of the silica in an ashless filter. Washed free from chlorides with hot water. The precipitate was dried, ignited and weighed in a platinum crucible as SiO_2. The weight of the SiO_2 in grams multiplied by 100 gave per cent of SiO_2 in sample.

DETERMINATION OF FERRIC OXIDE AND ALUMINA.

The filtrate from the silica was mixed with a little NH_4Cl solution to prevent the precipitation of Mg., and a very small excess of filtered NH_4OH was added. Heated to coagulate the hydroxides; allowed to settle and decanted the hot clear liquid through a filter. The precipitate was dissolved in a little dilute HCl, and the hydroxides reprecipitated with NH_4OH. The contents of the beaker was filtered through the same filter, and washed at once with hot water. Dried, ignited, and weigh-

ed residue in a porcelain crucible as Fe_2O_3 and Al_2O_3 and the percentage of both obtained as with silica.

SEPARATION OF FERRIC OXIDE.

The Fe_2O_3 and Al_2O_3 were disslored in dilute HCl, and evaporated to small bulk. Platinized zinc was then added until all the iron was reduced to ferrous oxide, as shown by the solution becoming colorless. The excess of zinc was next dissolved in H_2SO_4 and the solution allowed to cool thoroughly. Titrated with a standard $K_2Cr_2O_7$ solution (about .1 normal), and the amount of iron determined, using $K_3Fe(CN)_6$ as an indicator. From the amount of iron found, the percent of Fe_2O_3 was calculated. The percentage of Al_2O_3 was determined by the difference.

DETERMINATION OF CALCIUM OXIDE.

The alkaline filtrate from the determination of the Fe_2O_3 was evaporated down to a small volume. Added a few $(NH_4)_2C_2O_4$ crystals to the boiling solution, stirring until the oxalate was dissolved. Digested for an hour; decanted through a filter and washed with hot water. Dissolved the precipitate in dilute HCl, added a few oxalate crystals and then NH_4OH in excess; digested for an hour, decanted liquid, washed once by decantation and filtered.

The reprecipitation was necessary to prevent the precipitation of the magnesium with the calcium. The precipitate was CaC_2O_4. Dried, ignited, and weighed to constant weight in a crucible as CaO. The per cent of CaO was determined directly as in silica.

DETERMINATION OF MAGNESIA.

The filtrates from the calcium determination were evaporated to small bulk, and if crystals appeared they were dissolved in HCl. It was not necessary to rid the solution of Ammonium salts, for according to Hildebrand, Chief Chemist, U. S. Bureau of Standards, ammonium salts do not effect the determination of magnesium. The solution was made thoroughly cold, and then NH_4OH was added in excess. A small amount of a solution of sodium ammonium phosphate was then added, and the solution allowed to stand over night. Filtered and washed thoroughly with water, containing a little NH_4OH. Dried, ignited, and weighed the precipitate in a platinum crucible as $Mg_2P_2O_7$ from which the per cent of MgO was easily calculated. The residue required long heating over a hot blast lamp before all the ammonium and sodium salts were driven off and constant weight obtained.

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CHEMICAL ANALYSIS OF BRICK.

Make of brick.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.
Metropolitan.	64.66	21.15	8.21	2.56	2.32	1.23
Purington.	68.47	19.34	7.74	2.68	1.86	--
Barr.	60.73	22.20	10.95	2.95	2.02	1.06
Western.	65.33	21.30	8.38	2.47	2.08	--
# Flint.	63.75	19.78	5.75	1.55	1.22	1.74
# Capital City.	58.36	22.33	2.87	3.60	1.44	1.37
# Iowa.	65.22	19.22	3.35	2.99	1.44	2.18
# Merrill.	57.64	16.22	10.32	1.78	1.58	14.58

Analysis obtained from Iowa Geological Survey, Vol. XIV. 1903.

METHODS EMPLOYED IN MAKING PHYSICAL TESTS AND DESCRIPTION OF APPARATUS USED.

RATTLER TEST.

Prof Orton of the Ohio State University first devised a method for carrying on rattle tests for brick, which consisted of rattling the brick in an iron barrel. The volume of the brick used being about 15% of the volume of the rattler, and nothing but the brick were in the barrel. Experience with this method of testng soon led to abandoning it, on account of the non-uniformity of the results obtained. The method now in use was developed by Prop. A. N. Talbot, of the University of Illinois, and is the one we used. This method being accepted as the best form of rattler test, and has been adopted as standard by the National Brick Manufacturer's Association.

THE MACHINE OR RATTLER.

The machine used in these tests was constructed in accordance with the standard specifications, and was twenty eight inches in diameter, and twenty inches long. A cross section of the rattler was a regular polygon of fourteen sides. The heads were of ordinary grey cast iron four inches thick. The staves were made of boiler plate steel, and were six inches wide and one half inch thick, having about three eights inch space between staves to

allow dust and small pieces of waste to escape.

THE CHARGE.

All tests were executed on charges containing but one make of brick at a time. The charge consisted of the brick to be tested, and the abrasive material. The brick charge consisted of that number of whole bricks whose combined volume most nearly amounted to 8% of the cubical contents of the rattler. This was either eight or nine bricks, depending upon the size of the bricks. The abrasive cherge consisted of three hundred pounds of shot made of ordinary cast iron. The shot were of two sizes, the larger being 6.75 inches long and 2.5 inches square, while the former were 1.5 inch cubes; the edges of both being rounded. The shot charge consisted of 75 pounds of the larger size, and 225 pounds of the smaller size.

THE TEST.

The bricks were thoroughly dried before they were rattled. The duration of each test was 1800 revolutions at a speed of 30 R.P.M. The belt power being sufficient to keep this uniform. Two different tests were made for each kind of brick, one being for a continuous run of 1800 revolutions, and the other being stopped every 300 revolutions to permit the bricks to be weighed, in order to determine the rate of wear.

The bricks were weighed at the beginning and end of each period, and so the loss determined. The loss was then calculated in percentage of the weight of the dry brick composing the charge. Curves were plotted from the results obtained from the intermittent run.

ABSORPTION TEST.

The absorption test has been standardized by the National Brick Manufacturer's Association, and our tests were made in accordance with their recomendations. The tests were made on brick that had been previously rattled, so that the outer skin of glass was removed. Five bricks of each kind were dried in an oven at about 140° C. for forty eight hours, and weighed to within .002 of a pound. They were then placed in a large tank of pure water, and allowed to absorb the water. They were weighed at the expiration of 24, 48, 72, and 168 hours, being wiped dry each time before weighing. Curves were drawn showing the characteristic rate at which the bricks absorbed water. The weight of water absorbed being considered in per cent of the original weight of the brick.

TRANSVERSE TEST.

All transverse tests were made with a 20,000 pound Riehle Testing Machine. The bricks were placed on edge, and supported near each end by knife edges rounded both ways, and placed six inches apart; the load was applied in the center of this span by a similar knife edge. Care was taken that all knife edges were parallel to the surface of the brick at place of contact. The breaking load was the only load determined. Five brick were tested of each kind, and the fracture noted in every instance, and also imperfections in the manufacture that would be liable to influence the breaking.

As a means of comparing results from tests on different sizes of brick, the modulus of rupture for each test was found from the formula:-

$$M = \frac{3\ W\ l}{2\ b\ d^2}$$

where W is the breakind load in pounds.

l is the span in inches.

b is the breadth of brick in inches.

d is the depth of brick in inches.

DATA FROM YHE RATTLING TESTS.

METROPOLITAN BRICK.

Intermittent run.

Duration of run in R.P.M.	Weight before.	Weight after	Loss-lbs.	% loss
300	75	71.00	4.00	5.33
600	75	69.00	6.00	8.00
900	75	68.25	6.75	9.00
1200	75	67.00	8.00	10.66
1500	75	66.00	9.00	12.00
1800	75	65.25	9.75	13.00
		Continuous run.		
1800	76	65.75	10.25	13.33

PURINGTON BRICK.

Intermittent run.

Duration of run R.P.M.	Weight before.	Weight after	Loss-lbs.	% loss
300	70	66.00	4.00	5.75
600	70	63.75	6.25	8.93
900	70	62.50	7.50	10.71
1200	70	61.50	8.50	12.14
1500	70	60.75	9.25	13.21
1800	70	59.75	10.25	14.94
		Continuous run.		
1800	77.25	66.50	10.75	14.04

BARR BRICK.

Intermittant run.

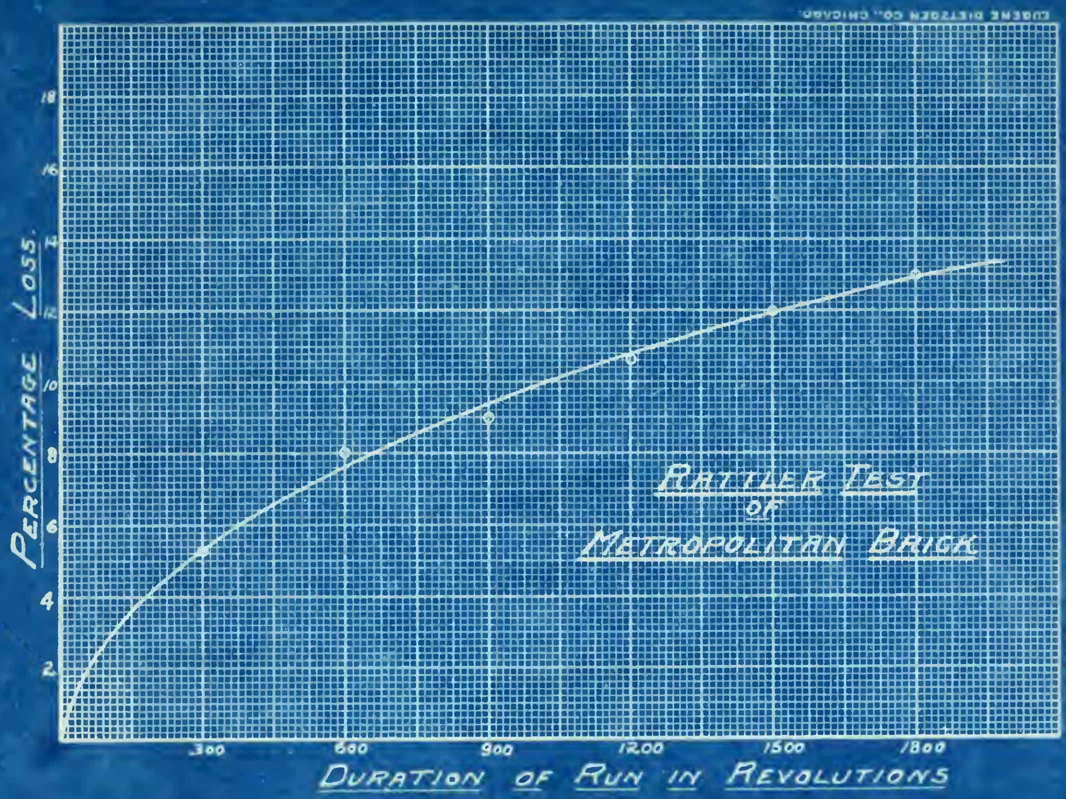
Duration of run in R.P.M.	Weight. Before.	Weight After.	Loss - lbs.	% loss.
300	72.75	67.75	5.00	6.87
600	72.75	66.00	6.75	9.28
900	72.75	64.25	8.50	11.68
1200	72.75	63.00	9.75	12.02
1500	72.75	62.00	10.75	13.40
1800	72.75	61.00	10.75	16.15
		Continuous run.		
1800	71.00	59.75	11.25	15.84

WESTERN BRICK.

Intermittant run.

Duration of run in R.P.M.	Weight Before.	Weight After.	Loss - lbs.	% loss.
300	73.25	66.25	7.00	9.55
600	73.25	63.50	9.75	11.94
900	73.25	61.75	11.50	15.22
1200	73.25	60.75	12.50	17.06
1500	73.25	59.75	13.50	19.90
1800	73.25	58.25	15.00	20.48
		Continuous run.		
1800	72.25	57.75	14.50	20.69

PLATE I.



EUGENE DIETZGEN CO., CHICAGO
RATTLER TEST
OF
METROPOLITAN BRICK
PERCENTAGE LOSS
2
4
6
8
10
12
14
16
18
300
600
900
1200
1500
1800
DURATION OF RUN IN REVOLUTIONS

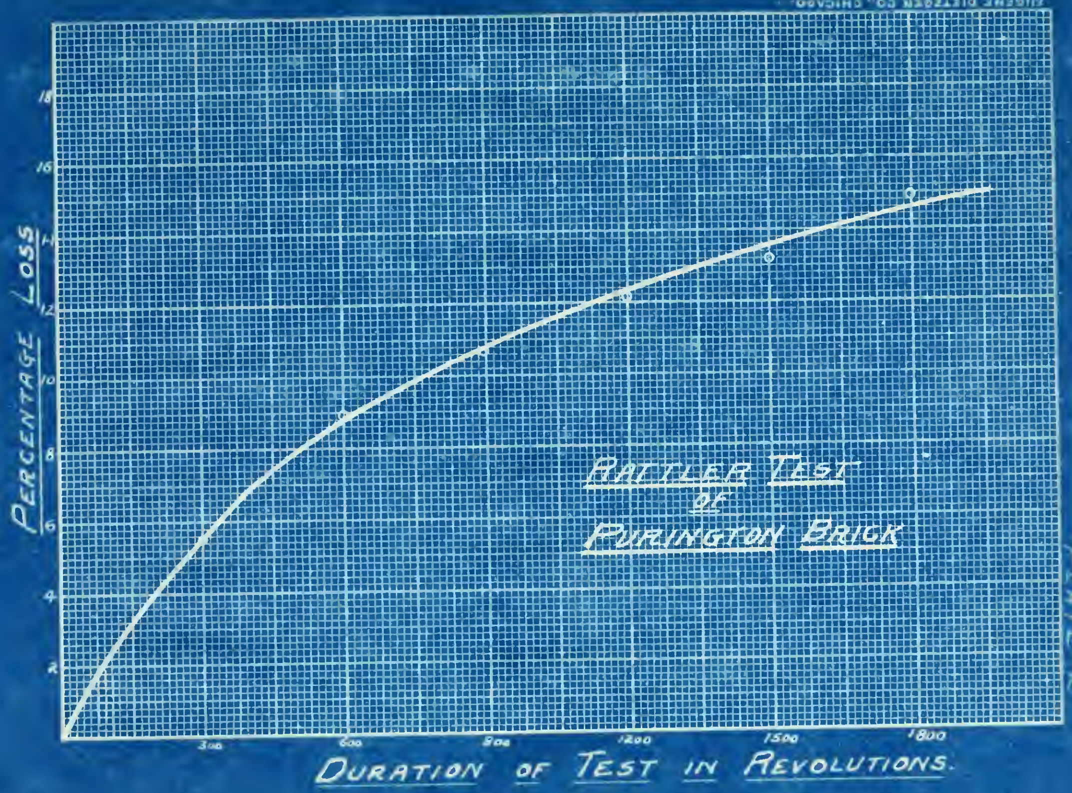
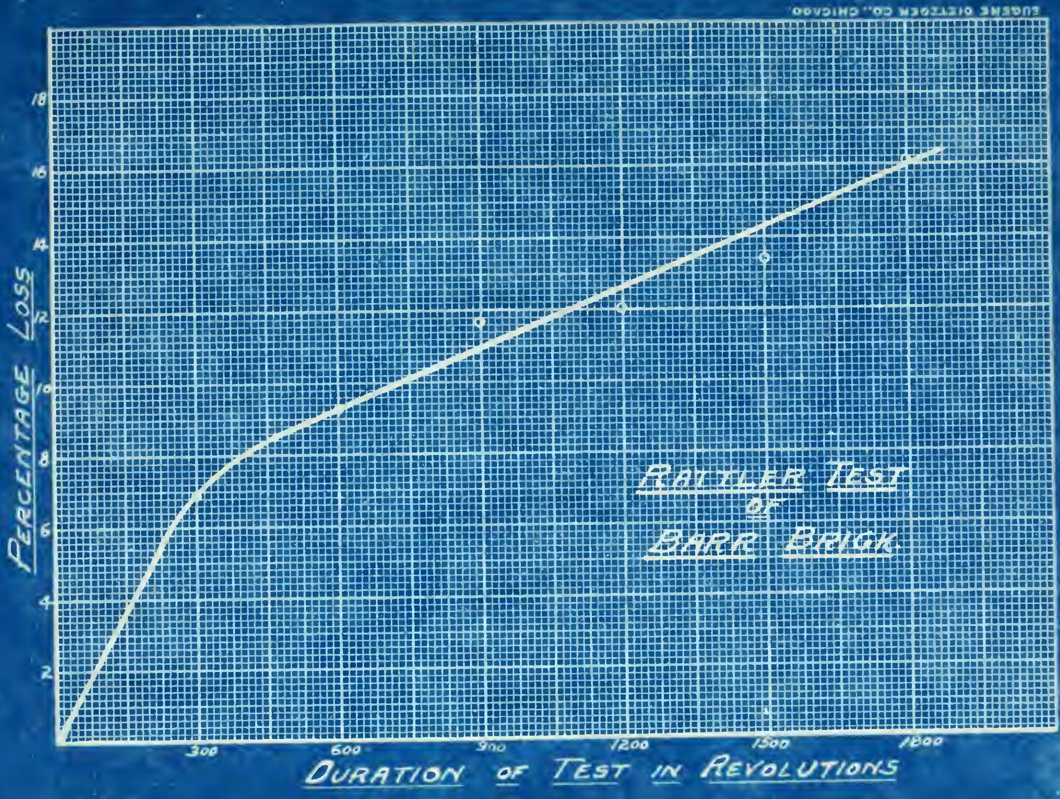

EUGENE DIETZGEN CO. CHICAGO.
Rattler Test
of
Purington Brick
Percentage Loss
2
4
6
8
10
12
14
16
18
300
600
900
1200
1500
1800
Duration of Test in Revolutions.

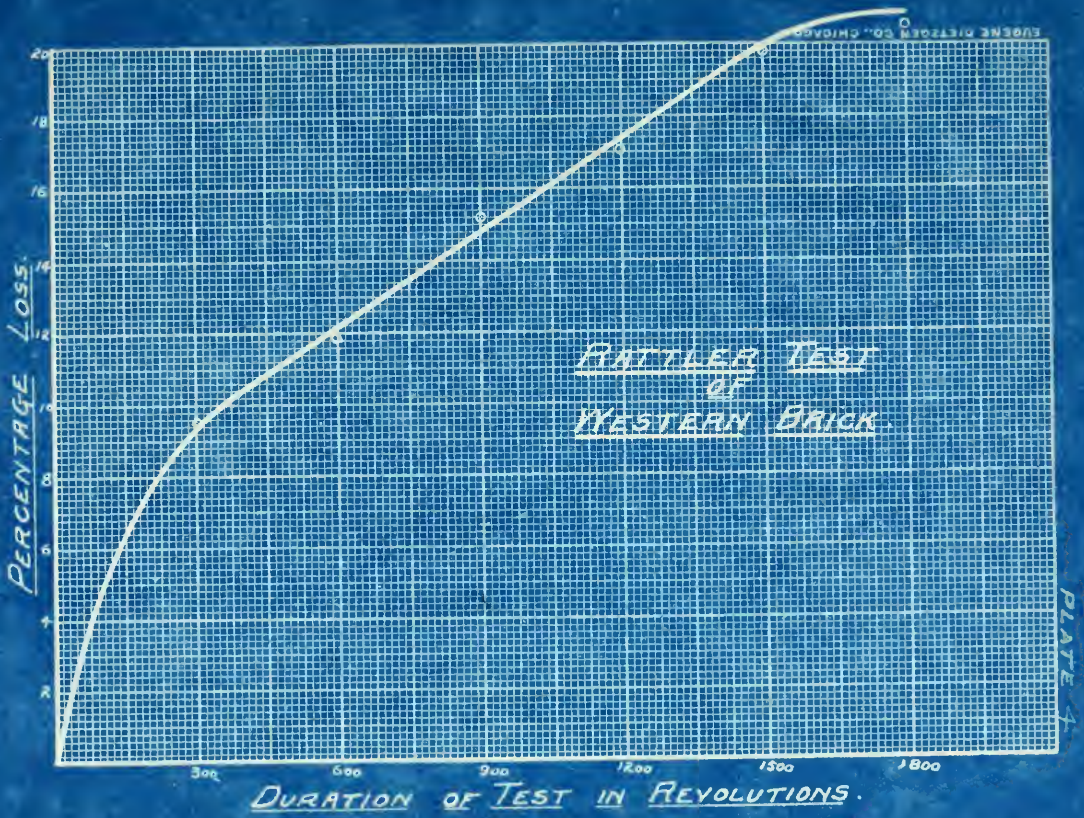
PLATE 2

PLATE 5



RATTLER TEST OF BARR BRICK
PERCENTAGE LOSS
2
4
6
8
10
12
14
16
18
300
600
900
1200
1500
1800
DURATION OF TEST IN REVOLUTIONS
EUGENE DIETZGEN CO., CHICAGO

PLATE 4



RATTLER TEST
OF
WESTERN BRICK.
PERCENTAGE LOSS.
20
18
16
14
12
10
8
6
4
2
300
600
900
1200
1500
1800
DURATION OF TEST IN REVOLUTIONS.
EUGENE DIETZGEN CO., CHICAGO

DATA FROM TRANSVERSE TESTS.

METROPOLITAN BRICK.

Dimensions of specimen:-

Length 6 in. Breadth 3 5/16 in. Thickness 3 15/16 in.

Number run.	Breaking load.	Modulus of fracture.	Appearance of fracture.
1	20,000	9,205,000	Smooth and regular.
2	18,700	8,607,000	" " "
3	18,900	8,800,000	" " "
4	15,700	7,236,000	Large flaw shown.
5	17,300	8,063,000	Irregular and splintered.
Average,	18,100	8,331,000	

PURINGTON BRICK.

Dimensions of specimen:-

Length 6 in. Breadth 3.5 in. Thickness 3.75 in.

Number run.	Breaking load.	Modulus of fracture.	Appearance of fracture.
1	22,000	9.745,000	Very smooth.
2	18,000	7,973,000	Smooth with cracks.
3	17,500	7,751,000	Splintered.
4	17,000	7,530,000	Very uneven.
5	9,000	3,986,000	Very large flaw.
Average,	16,700	7,397,000	

BARR BRICK.

Dimensions of specimen:-

Length 6 in. Breadth 3.375 in Thickness 3.75 in.

Number run.	Breaking load.	Modulus of fracture.	Appearance of fracture.
1	19,300	8,242,000	Chipped slightly.
2	17,400	7,330,000	Smooth and regular.
3	16,700	7,131,000	Splintered.
4	15,300	6,538,000	Broke in pieces, flaw.
5	16,900	7,217,000	Splintered.
Average,	17,120	7,311,000	

WESTERN BRICK.

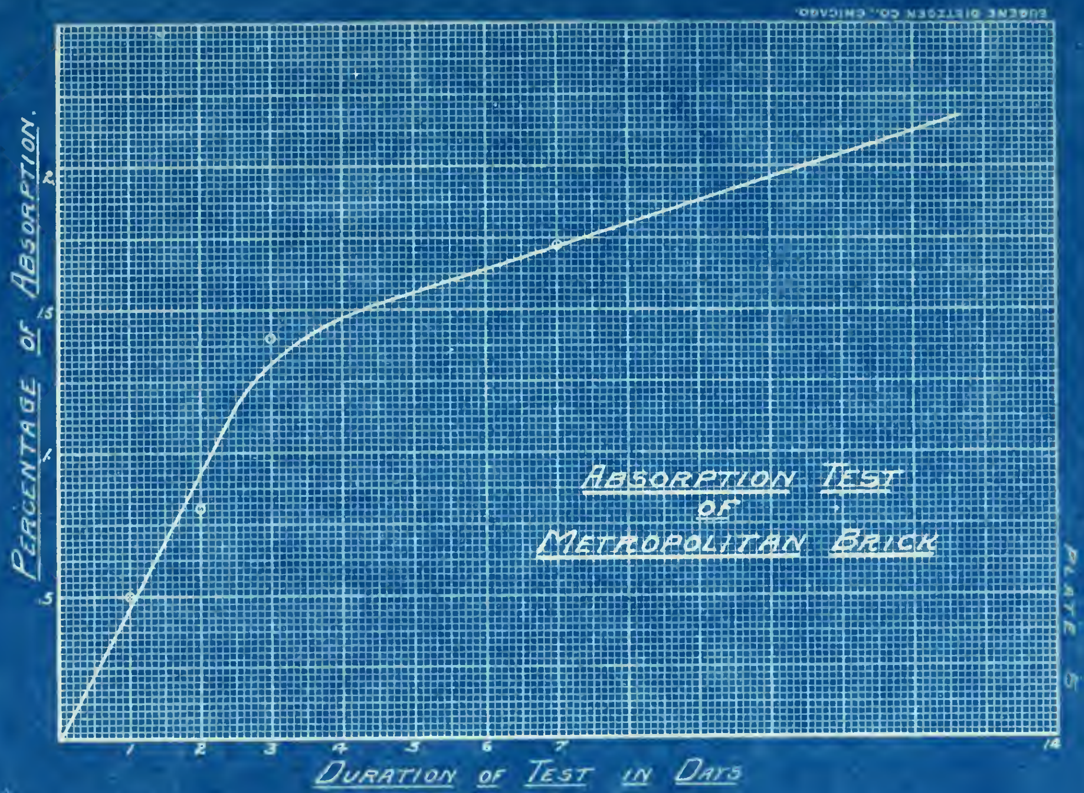
Dimensions of specimen.

Length 6 in. Breadth 3.125 in. Thickness 3.937 in.

Number run.	Breaking load.	Modulus of fracture.	Appearance of fracture.
1	14,700	6,266,000	Smooth and regular.
2	8,500	3,623,000	Flaw on one side.
3	15,100	6,437,000	Good fracture.
4	14,000	5,968,000	Splintered.
5	15,300	6,522,000	Very good, smooth.
Average,	13,520	5,763,000	

DATA FROM ABSORPTION TESTS.

Kind of brick.	Duration of run-hrs.	Weight before.	Weight after.	Gain-lbs.	% gain.
Metropolitan.....	24	41.82	42.03	0.21	.50
	48	41.82	42.16	0.34	.81
	72	41.82	42.30	0.58	1.41
	168	41.82	42.55	0.73	1.72
Purington........	24	37.89	38.06	0.17	.44
	48	37.89	38.09	0.20	.52
	72	37.89	38.14	0.25	.66
	168	37.89	38.14	0.25	.66
Barr	24	38.73	38.95	0.22	.57
	48	38.73	39.06	0.33	.85
	72	38.73	39.08	0.35	.90
	168	38.73	39.15	0.42	1.08
Western..........	24	37.94	39.07	1.13	3.00
	48	37.94	39.20	1.26	3.32
	72	37.94	39.24	1.30	3.42
	168	37.94	39.30	1.36	3.56


EUGENE DIETZGEN CO., CHICAGO.
PERCENTAGE OF ABSORPTION.
.5
1.
1.5
2.
1
2
3
4
5
6
7
14
ABSORPTION TEST
OF
METROPOLITAN BRICK
DURATION OF TEST IN DAYS
PLATE 5

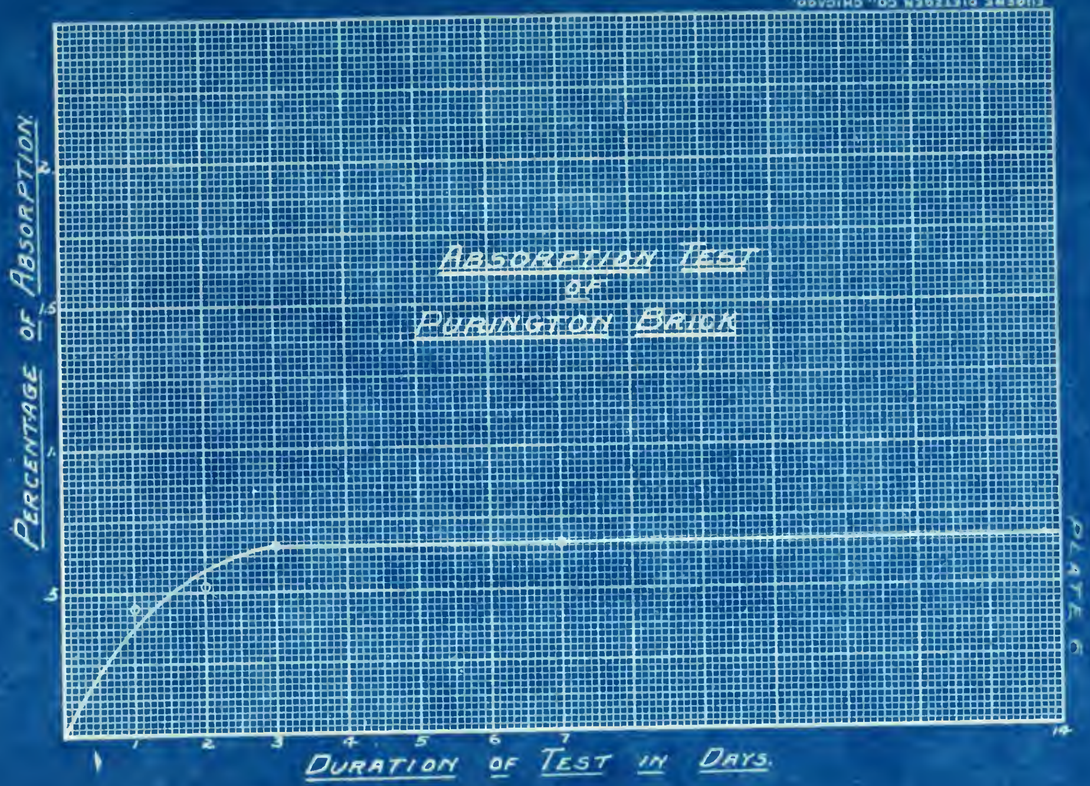


PLATE 6
ABSORPTION TEST
OF
PURINGTON BRICK
PERCENTAGE OF ABSORPTION
.5
1.
1.5
2.
1
2
3
4
5
6
7
14
DURATION OF TEST IN DAYS.
EUGENE DIETZGEN CO., CHICAGO.

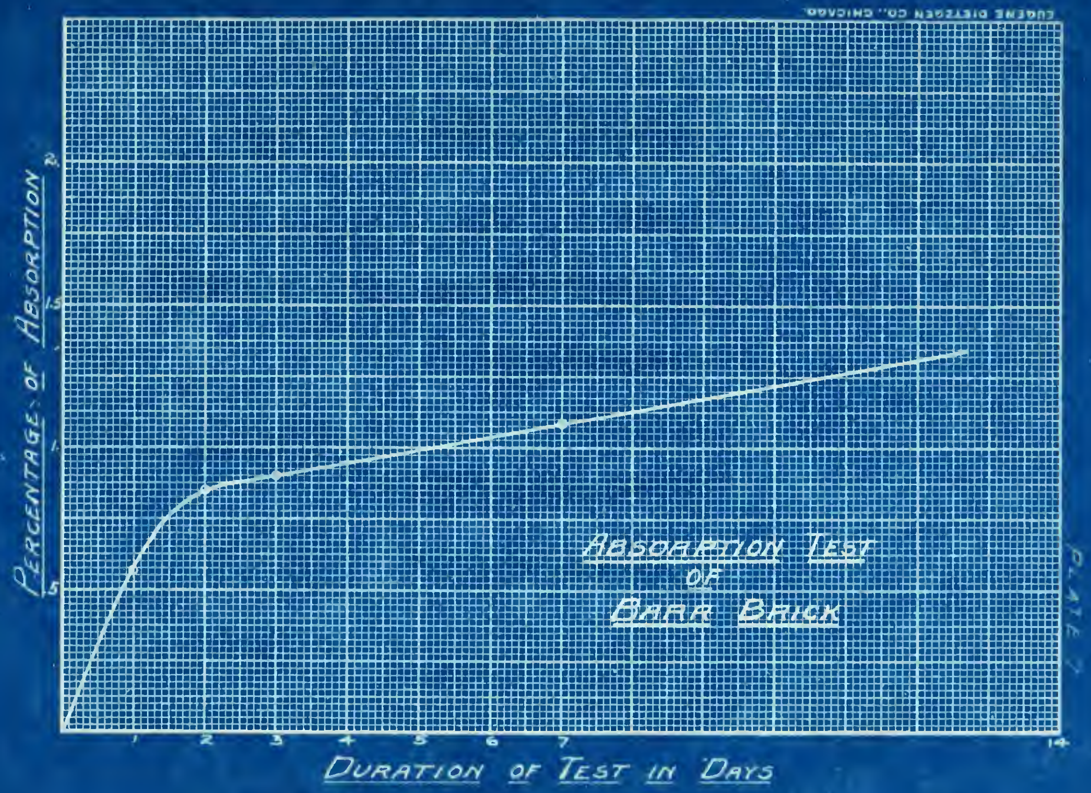


PLATE 7
ABSORPTION TEST OF BARR BRICK
PERCENTAGE OF ABSORPTION
.5
1.
1.5
2.
1
2
3
4
5
6
7
14
DURATION OF TEST IN DAYS
EUGENE DIETZGEN CO., CHICAGO

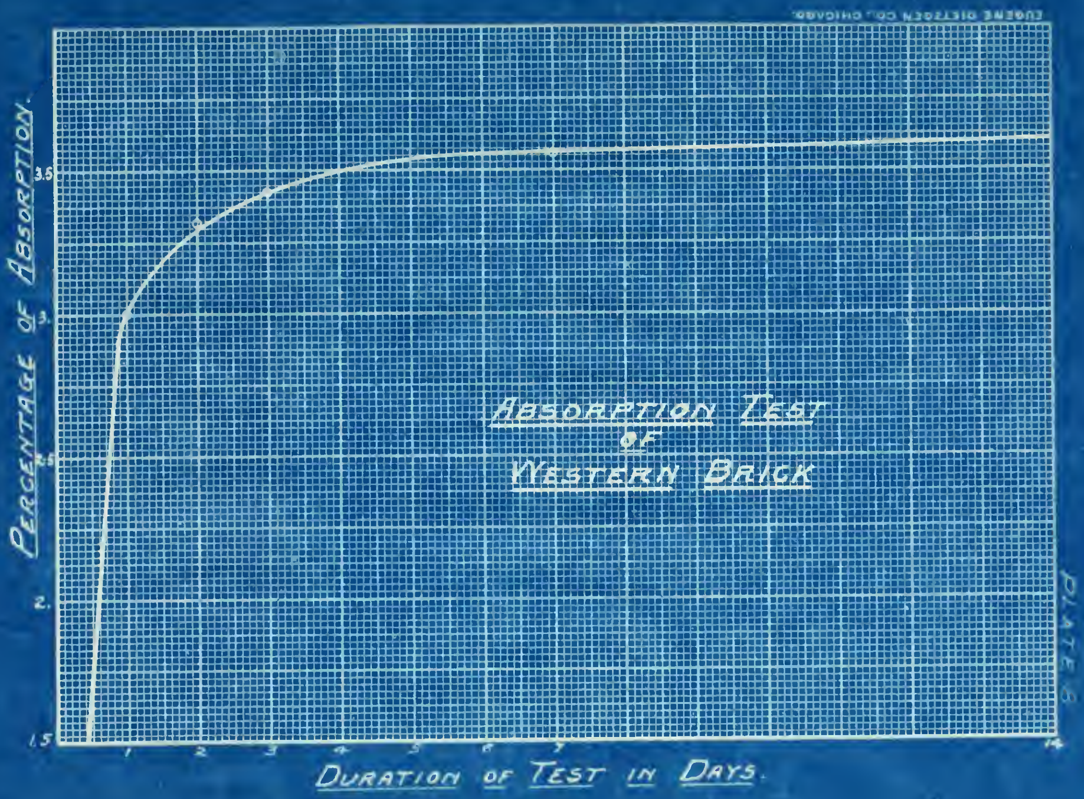


PLATE 8
ABSORPTION TEST
OF
WESTERN BRICK
PERCENTAGE OF ABSORPTION.
3.5
3.
2.5
2.
1.5
1
2
3
4
5
6
7
14
DURATION OF TEST IN DAYS.
EUGENE DIETZGEN CO., CHICAGO.

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DISCUSSION OF THE RESULTS OBTAINED FROM PHYSICAL TESTS.

RATTLER TEST.

The rattler test for paving brick has come to be accepted as the most reliable for determining theit ability to withstand hard usuage. It is supposed to subject the bricks to the same wear and tear as they receive in actual use from the blows of the horses' hoofs, and grinding caused by the wheels of vehicles. In the rattler test the brick pound against each other, the sides of the rattler, and the charge in a way to produce excessive wear, mainly by abrasion, and the brick fail in a manner somewhat the same as when in actual use on the street.

The greater part of the wear was noticed to occur during the first 300 revolutions, and the loss was principally due to chipping and breaking off of the edges and corners. After that, the loss was more gradual and mainly by abrasion, all edges becoming rounded. Wherever an imperfection in material, as a small pebble, or manufacture occurred a pit was worn into the face of the brick. This imperfection in manufacture was mainly that due to the difference in fineness of the material before burning, and the results show that to give even wear the material should be homogeneous.

ABSORPTION TEST.

The absorption test was made on rattled bricks so as to make this test follow as closely as possible the conditions in actual use. The outside of the brick as they come from the kiln, is covered with a glaze which would retard the absorption of the water, and as this glaze is worn of after a small amount of use in a street, the test was carried on upon rattled brick.

A good brick should not absorb much moisture, for if it does the brick becomes weaker, and is liable to crack, should this moisture freeze. The only perceivable effect of the absorption test on the brick, was a tendency to crumble after they had been in the water a couple of days.

TRANSVERSE TEST.

This test is held in very high esteem by some authorities, as a reliable means of determining the quality of paving brick. While the rattler test gives a good indication of the wearing quality of the surface, still it does not show any defects in the interior of the brick, which might cause a crack or rupture with a heavy load. So we might say that the test is not only intended to augment the rattler test, but it also discovers any hidden flaws caused by unevenness of material, or improper pressing or burning.

The results show that a brick, which gave good results in the rattler test, also gave good results inthis test, and that whenever a real low value of breakingbload was found, it was due to some flaw. As the results from transverse tests show the same characteristics as would crushing tests on the brick, we omitted the latter from our results. A few tests were at first performed, but as the data was not at all uniform for successive tests on the same brick, we have omitted the results from our paper.

CONCLUSIONS AND COMPARISONS DRAWN FROM RESULTS OF EXPERIMENTS.

EFFECT OF PERCENTAGE OF SiO_2 UPON PHYSICAL PROPERTIES.

RATTLER TEST.

From diagrams on plate IX of SiO_2 and rattle test, the following conclusion seems highly probable, being upheld by the results of most of the bricks testsed; viz:- the greater the percentage of SiO_2, the smaller the loss in the rattler, this being especially noticable when the SiO_2 falls below 60%.

ABSORPION TEST.

While thr relations between percentage of SiO_2 and absorption values are not as marked as with rattler values, still there is a possible generalization which may be drawn, that will include all the bricks but one; viz:- the greater the percentage of silica, the smaller the gain due to absorption, this being particularly noticable when the SiO_2 falls below 60%, or above 68%. In the one exception to this generalization it will be seen that the percentage of Fe_2O_3 is exceptionally low, which may explain the discrepency, making a low SiO_2 brick have a good absorption value.

TRANSVERSE TEST.

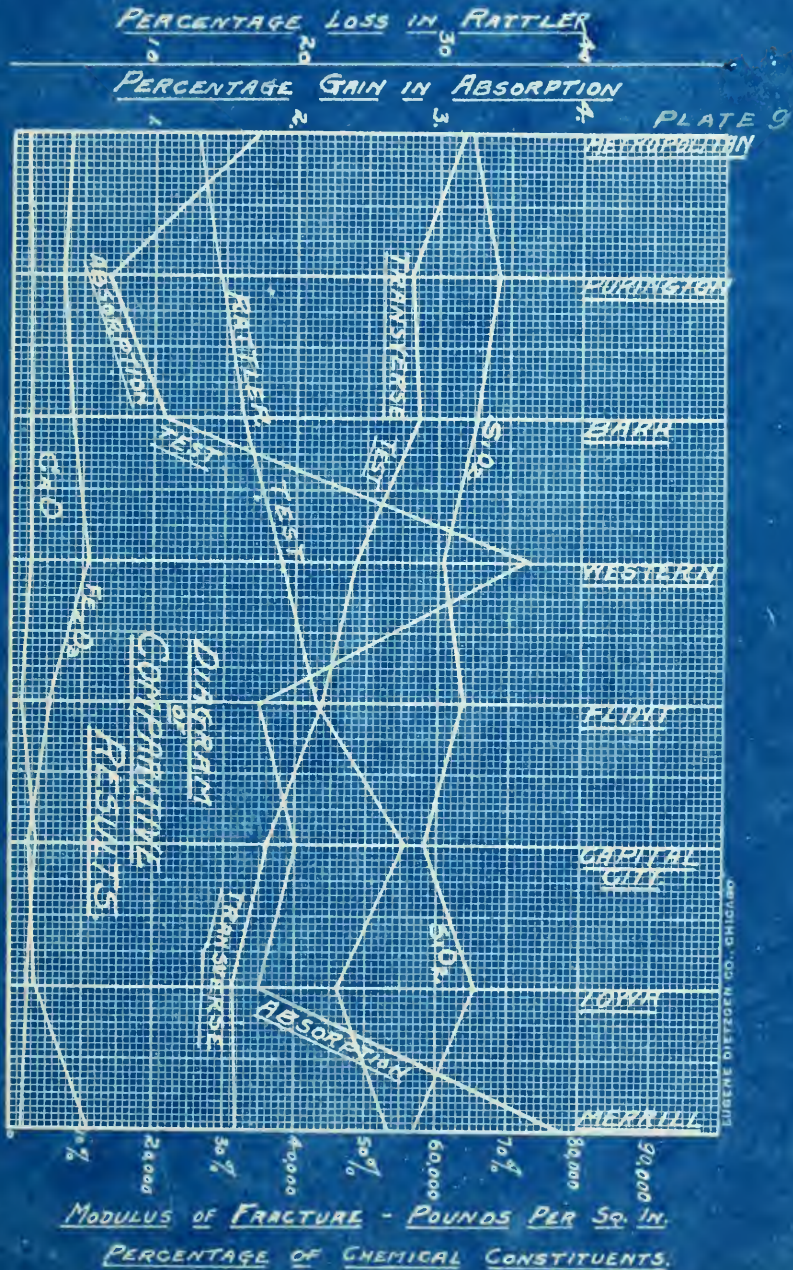
While the method and carefullness of manufacture have undoubtly most to do with values found in the transverse tests, as was noticed in several cases described elsewhere, a brick containing a high per cent of SiO_2 does give the best value of modulus of fracture per square inch of cross sectional area, and so we are justified in drawing thsi conclusion, viz:- the greater the percentage of SiO_2 the greater the value of the modulus of fracture per square inch of cross sectional area.

EFFECT OF PERCENTAGE OF FERRIC OXIDE UPON PHYSICAL PROPERTIES.

The amount of irnn present seems to have little effect upon the values obtained in the rattler or transverse tests, but with the absorption values, the following generalization seems justified from the results obtained, viz:- the greater the percentage of Fe_2O_3 the greater the porosity of the brick. From the diagrams on plate IX, this will be seen to be true without exception.

EFFECT OF LIME, MAGNESIA AND ALUMINA UPON PHYSICAL PROPERTIES.

Lime, magnesia and alumina seem to have no effect upon the physical properties, which follow any definite law. Two or three values may seem to warrant a generalization, but as many more contradict it.



PERCENTAGE LOSS IN RATTLER
10 20 30 40
PERCENTAGE GAIN IN ABSORPTION
1. 2. 3. 4.
PLATE 9
METROPOLITAN
PURINGTON
BARR
WESTERN
FLINT
CAPITAL CITY
IOWA
MERRILL
ABSORPTION TEST
RATTLER TEST
TRANSVERSE TEST
SiO_2
CaO
Fe_2O_3
DIAGRAM OF COMPARATIVE RESULTS
TRANSVERSE
ABSORPTION
10% 20,000 30% 40,000 50% 60,000 70% 80,000 90,000
MODULUS OF FRACTURE - POUNDS PER SQ. IN.
PERCENTAGE OF CHEMICAL CONSTITUENTS.
EUGENE DIETZGEN CO. CHICAGO

RESUME.

While the above conclusions were arrived at from the results obtained, the physical defects caused by improper gringing, pressing or burning have the greatest effects upon the mechanical tests, but where all the bricks are made properly and in the same manner, we believe the generalizations reached by comparisons of chemical properties are correct.