CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF MINES

THE PHYSICAL PROPERTIES OF CANADIAN STRUCTURAL TILE

(Made from Clay or Shale)

BY

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The Physical Properties of Canadian Structural Tile
(Made from Clay or Shale)

INTRODUCTION

This report is a sequel to the report on the "Physical Properties of Canadian Building Brick". The investigation was started in 1939 and completed in 1941, but, as in the case of the brick report, its publication was postponed owing to restrictions on the printing of reports during the war.

The prime purpose of this investigation was to assist the individual manufacturers by giving them a basis for evaluating their own products. However, it is hoped that the report will prove of value to architects, contractors, and others concerned with the use of structural tile, and possibly serve as a means of formulating more appropriate specifications.

The investigation embraced the complete testing of representative samples from all structural tile plants in Canada that were operating and could supply samples, but for obvious reasons efforts were made to avoid any indication as to the source of the individual samples.

THE COLLECTION OF SAMPLES

After consultations with manufacturers, architects, etc., the tile samples to be used in the investigation were collected in accordance with the following plan. At each plant an endeavour was made to select that kind and size of tile for which there was the greatest demand, and which was most likely to be used in exterior walls. Throughout Ontario and Quebec, visits were made to the various plants for the purpose of selecting the samples and obtaining information relative to their manufacture. In Western Canada and in the Maritime Provinces, instructions for selecting and submitting representative tile specimens were forwarded to the plants and the samples were shipped to Ottawa. In most cases each sample lot consisted of fifteen individual specimens that were selected to represent the average product marketed. For samples of tile manufactured specially for use in exterior or exposed walls, precautions were taken to exclude those specimens showing cracks or other defects.

The sample lots collected for investigation were as follows:

19	sample	lots	4 × 12 × 12	3-cell
1	"	"	3 × 12 × 12	3-cell
5	"	"	8 × 5 × 12	speed tile
1	"	"	8 × 8 × 12	4-cell
1	"	"	8 × 8 × 12	speed tile
5	"	"	4 × 8 × 12	2-cell
7	"	"	5 × 8 × 12	2-cell
1	"	"	4 × 8 × 12	3-cell
9	"	"	5 × 8 × 12	3-cell
1	"	"	4 × 5 × 12	2-cell
1	"	"	8 × 5 × 12	special shape
1	"	"	6 × 12 × 12	3-cell
1	"	"	6 × 8 × 12	3-cell
4	"	"	Interlocking tile	
1	"	"	5 × 6 × 12	2-cell
1	"	"	8 × 12 × 12	6-cell

Thirty-six Canadian plants manufacturing structural tile (made from clay or shale) contributed samples.

METHOD OF TESTING

COMPRESSIVE STRENGTH

Compressive strength determinations were made in accordance with the method prescribed by the American Society for Testing Materials. The design of the tile governed the direction in which the load was applied, that is, the tiles were placed in the testing machine in such manner that the load was applied in the same direction that it would be applied when the tiles are laid up in walls. The tiles were capped on both bearing surfaces to provide level and parallel surfaces. The capping was kept between $\frac{1}{16}$ and $\frac{1}{8}$ inch in thickness, and consisted of a mixture of 75 per cent Portland cement and 25 per cent plaster of Paris. These tests were made with an Amsler compression machine; the rate of application of load being constant for all tests.

In general, the type of failure under load fell into one of three classes:

(1) *Web Failure.* In this class the webs failed first, usually along the contact with one wall. This failure, accompanied by a drop in the pressure reading on the dial, would often occur at a pressure considerably below that at which complete failure of the tile took place. As the load was applied the side walls tended to bulge outward and thus placed the webs under tension. After the webs had failed, the side walls continued to take the load until final failure occurred; due to the side walls shearing from the top or base, or completely collapsing. (*See* Plate IA.)

(2) *Failure Due to Shear.* In such cases one or both side walls failed in shear, as illustrated in Plates IB and IIA.

(3) *Failure by Complete Collapse and Shattering of the Tile.* Hard-burned and brittle tile, which would suddenly collapse at maximum load and break into numerous pieces, fell into this class. Failure was not due to weak sections in the tile giving way, but rather to the whole tile breaking up at ultimate load. Plate IIB shows a typical tile of this class.

ABSORPTION AND ABSORPTION RATIO

Percentage absorption was determined after soaking in cold water for 5 hours and 48 hours, and after subsequent boiling for 5 hours. The figures appearing under ratio "A" were obtained from the ratio:

$$\frac{\text{5 hrs. cold absorption}}{\text{5 hrs. boil absorption}}$$

The figures under ratio "B" were obtained from the ratio:

$$\frac{\text{48 hrs. cold absorption}}{\text{5 hrs. boil absorption}}$$

These ratios are important since it has been found, in the case of brick at least, that they give an indication of weather resistance. Ratio B (C_{48}/B_5 ratio) is the more important indicator. In general, the lower this ratio is, the more resistant the tile should be to frost action. A tile having a "B" ratio of 0·85 or higher is likely to give trouble in damp walls exposed to repeated freezing and thawing.[1] Ratio "A" (C_5/B_5 ratio) is supposed to give some indication of rate of absorption.

[1] McBurney, J. W.: "The Relation of Freezing and Thawing Resistance to Physical Properties of Clay and Shale Building Brick"; Proc. A.S.T.M., vol. 35, Pt. I, p. 247 (1935).

Butterworth, B.: "The Correlation of Laboratory Tests with the Weathering Properties of Brick"; Trans. Ceram. Soc. (England), vol. 33, p. 495 (Nov. 1934).

McBurney, J. W., and J. C. Richmond: "Strength, Absorption and Resistance to Laboratory Freezing and Thawing of Building Bricks Produced in the United States"; Building Materials and Structures Report, BMS 60. (Nov. 1940.)

FREEZING AND THAWING

For convenience of handling in the freezing and thawing tests, samples approximately 6 inches long were cut from whole tile. Fifty sample lots of three tile each were subjected to fifty cycles of alternate freezing and thawing. The samples were first soaked in water for 48 hours and the per cent absorption determined. They were then set in a shallow pan containing from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches of water and placed in a refrigeration chamber maintained at 20°F. for 16 hours. The frozen tile were taken from the freezer and completely submerged in a tank of water at room temperature for 8 hours, after which they were carefully inspected, and the cycle was repeated. At the end of each ten cycles the wet tile were weighed, dried at 110°C, reweighed, and the per cent absorption calculated. Tile losing 1 per cent or more in weight were considered as having failed in freezing and thawing.

RESULTS OF TESTS

COMPRESSIVE STRENGTH

Average results of the compressive strength determinations are shown in Table III. The different sizes and designs of tile included in the entire number of samples were grouped, and averages and extremes in compressive strength for each group are given in Table I.

TABLE I

Compressive Strength, lb./sq. in. (Gross area)

Size	Average	Maximum	Minimum	Number of sample lots in average
4 × 12 × 12	963	2,135	470	19
8 × 5 × 12. Speed tile	2,622	2,885	2,166	5
4 × 8 × 12. 2-cell	750	986	592	5
5 × 8 × 12. 2-cell	596	757	390	7
5 × 8 × 12. 3-cell	688	1,351	415	9
Interlocking tile	896	1,052	604	4

ABSORPTION AND ABSORPTION RATIO

The averages and extremes in absorption data for the several groups are given in Table II. Table III is a composite table giving the average results of determinations of absorption properties, the average results of all other tests made, and other pertinent information. In Table IV, absorption data obtained on individual specimens are given with the results of the freezing and thawing tests. The data in Table IV are directly comparable, since the freezing and thawing tests were carried out on the same individual specimens from which the absorption data were taken.

TABLE II

Absorption Properties

Size	—	5 hrs. cold	48 hrs. cold	5 hrs. boil	Ratio A	Ratio B
4 × 12 × 12	Average....	11·12	11·95	13·78	0·78	0·85
	Highest....	18·29	19·03	21·60	0·90	0·93
	Lowest.....	5·58	6·83	8·22	0·61	0·73
8 × 5 × 12 Speed tile.	Average....	6·22	7·01	8·56	0·67	0·78
	Highest....	13·65	14·20	15·64	0·87	0·91
	Lowest.....	1·76	2·73	3·95	0·44	0·68
4 × 8 × 12 2-cell.	Average....	17·25	18·58	21·97	0·76	0·82
	Highest....	23·76	25·97	27·64	0·86	0·94
	Lowest.....	9·27	10·21	13·50	0·65	0·70
5 × 8 × 12 2-cell.	Average....	15·60	16·92	19·97	0·76	0·83
	Highest....	28·50	30·40	33·00	0·90	0·94
	Lowest.....	8·90	10·00	13·10	0·65	0·75
5 × 8 × 12 3-cell.	Average....	12·59	13·69	15·92	0·78	0·85
	Highest....	19·19	20·70	23·29	0·83	0·89
	Lowest.....	7·00	7·95	8·91	0·63	0·77
Interlocking tile	Average....	10·85	12·05	14·16	0·70	0·81
	Highest....	22·70	24·20	26·20	0·87	0·93
	Lowest.....	4·15	5·78	8·11	0·48	0·67

FREEZING AND THAWING

As mentioned under "Absorption and Absorption Ratio", the results of the freezing and thawing tests are given, with other pertinent data, in Tables III and IV. Table III gives average results obtained on at least three specimens; and Table IV gives individual results in accordance with increasing percentage absorption. Figure 1 was plotted from the data given in Table IV, and shows the relation between absorption data and resistance to freezing and thawing. In Figure 2, ranges of C_{48}/B_5 ratios are plotted against the percentages of tile that withstood fifty cycles of freezing and thawing.

The behaviour of the tile under conditions of freezing and thawing is seen to be very closely related to its absorption properties. No tile with an absorption of 10 per cent or less failed in fifty cycles of freezing and thawing. Of those tile with an absorption between 10 and $12\frac{1}{2}$ per cent, only 16 per cent failed to stand fifty cycles; and of all tile with an absorption of $12\frac{1}{2}$ per cent or more, 93 per cent failed in freezing and thawing. The relationship between C_{48}/B_5 ratio and freezing and thawing is also illustrated in Figure 1. No tile with a C_{48}/B_5 ratio less than 0·72 failed, and only 22 per cent of those that failed had a C_{48}/B_5 ratio less than 0·85; whereas two-thirds of those that withstood fifty cycles of freezing and thawing had a C_{48}/B_5 ratio less than 0·85.

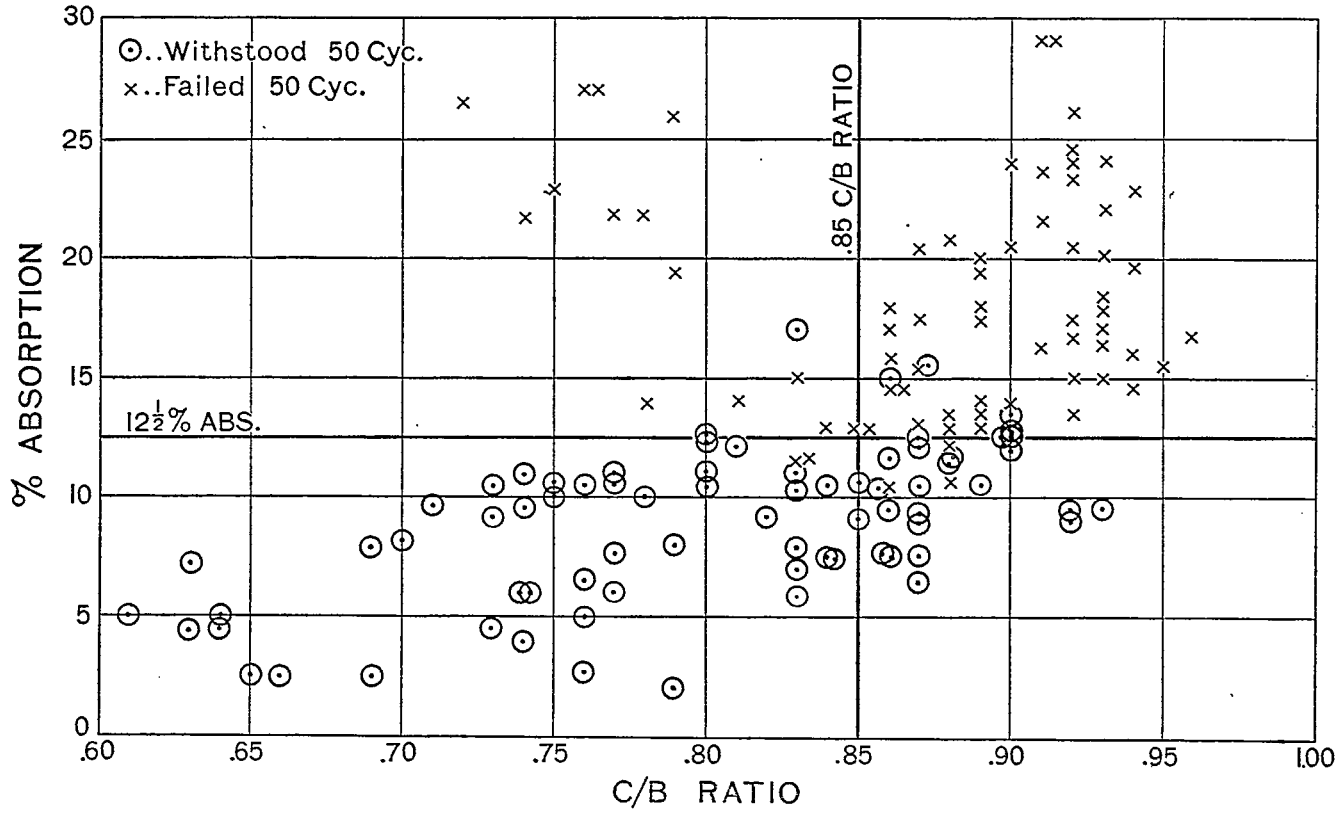


FIGURE 1.—Showing relation between freezing and thawing resistance and absorption data.

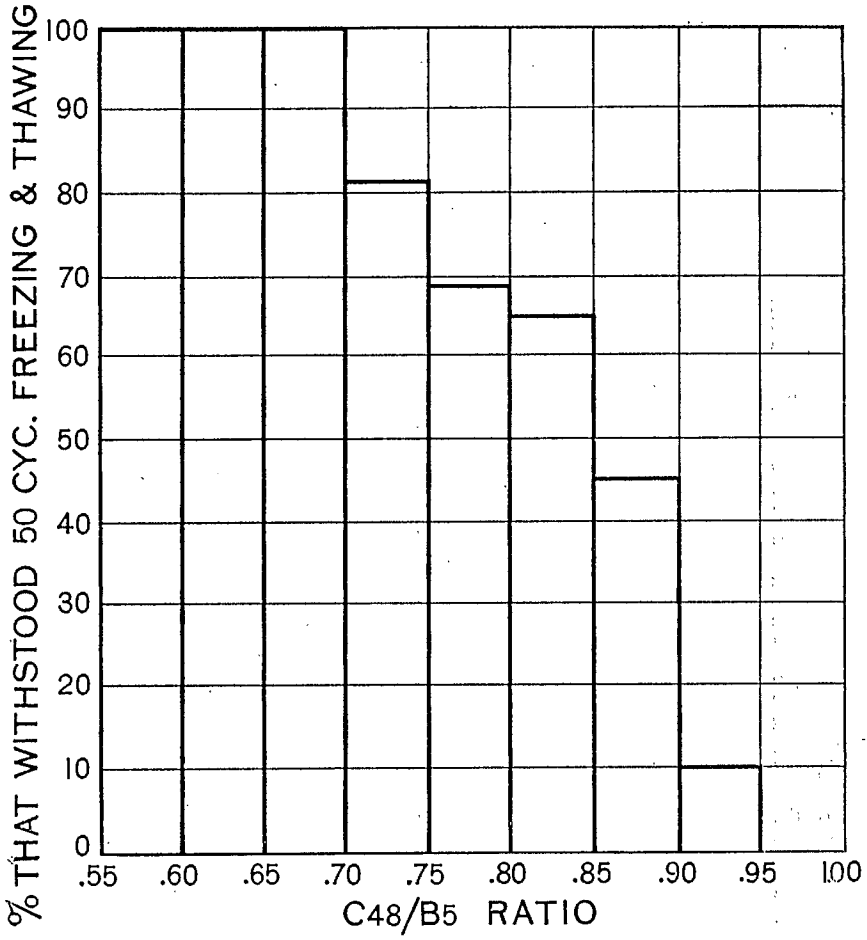


FIGURE 2—Ranges of $C_{48}B_5$ ratios plotted against the percentages of tile that withstood fifty cycles of freezing and thawing.

SUMMARY

Fifty-nine sample lots of building tile were tested for compressive strength, absorption properties, and ability to withstand repeated freezing and thawing. Various designs of tile and raw materials were represented in the tests. Compressive strengths ranged from a minimum of 390 pounds to a maximum of 2,885 pounds per square inch. Absorption after a 48-hour cold immersion and a 5-hour boil varied from a low of 3·95 per cent to a high of 33 per cent, and the C_{48}/B_5 ratio varied from a low of 0·58 to a high of 0·96. All tile with an absorption of 10 per cent or less after a 48-hour immersion in water at room temperature withstood fifty cycles of freezing and thawing; and all those with an absorption of 17 per cent or greater failed. Of the tile with an absorption between 10 and 17 per cent, thirty-three individual samples withstood fifty cycles and thirty-six individual samples failed.

TABLE III

Average Results of Determinations of Absorption Properties, Compressive Strength, and Freezing and Thawing

(All data given are average results obtained on at least three specimens.)

Sample No.	Description and raw material	Absorption data			Absorption ratio		Compressive strength		Freezing and thawing		Remarks
		Per cent absorption									
		5 hours cold	48 hours cold	5 hours boil	C_5/B_5	C_{48}/B_5	Gross area, lb./sq. in.	Net area, lb./sq. in.	Initial failure, cycle No.	Final failure, cycle No.	
1	3 × 12 × 12. Surface clay and sand.....	8·37	9·08	11·72	0·71	0·77	2,135	5,048	O.K.	O.K.	Medium hard, good structure
2	4 × 12 × 12. Porous partition tile made with sawdust.....	24·07	25·55	35·53	0·68	0·72	520	1,376	2	50	.....
3	4 × 12 × 12. Clay and shale.....	8·63	9·28	10·29	0·84	0·90	732	2,757	O.K.	O.K.	Medium hard, good structure
4	4 × 12 × 12. Surface clay and sand.....	7·97	8·65	10·56	0·66	0·75	1,262	3,812	29	50	Medium hard, laminated
5	4 × 12 × 12. Shale.....	15·00	15·93	17·34	0·86	0·92	1,113	2,903	8	40	Medium hard, fair structure
6	4 × 12 × 12. Surface clay.....	12·39	13·02	15·16	0·82	0·86	871	2,152	11	25	Medium hard, laminated
7	4 × 12 × 12. Surface clay.....	14·87	15·84	17·20	0·86	0·92	470	1,639	4	18	Soft, laminated
8	4 × 12 × 12. Clay.....	18·29	19·03	20·38	0·90	0·93	495	1,434	4	23	Soft, laminated
9	4 × 12 × 12. Clay.....	11·09	11·77	13·78	0·80	0·85	649	1,888	5	50	Medium hard, brittle
10	4 × 12 × 12. Shale.....	7·71	8·63	10·15	0·76	0·85	879	3,183	O.K.	O.K.	Hard
11	4 × 12 × 12. Shale.....	9·72	10·18	12·76	0·75	0·79	887	2,839	20	50	Hard, good structure.....

TABLE III—Continued

Average Results of Determinations of Absorption Properties, Compressive Strength, and Freezing and Thawing

Sample No.	Description and raw material	Absorption data			Absorption ratio		Compressive strength		Freezing and thawing		Remarks
		Per cent absorption									
		5 hours cold	48 hours cold	5 hours boil	C_5/B_5	C_{48}/B_5	Gross area, lb./sq. in.	Net area, lb./sq. in.	Initial failure, cycle No.	Final failure, cycle No.	
12	4 × 12 × 12. Clay and shale	12·82	13·26	15·01	0·85	0·88	1,221	3,980	17	40	Hard, good structure
13	4 × 12 × 12. Shale	8·42	9·60	11·35	0·74	0·84	1,058	3,193	O.K.	O.K.	Hard
14	4 × 12 × 12. Surface clay	17·72	18·89	21·60	0·82	0·87	704	2,324	.....	.....	Soft, laminated
15	4 × 12 × 12. Surface clay	9·87	10·66	13·50	0·66	0·73	680	2,161	.....	.....	Medium hard, laminated
16	4 × 12 × 12. Surface clay	12·28	13·30	14·88	0·83	0·90	1,049	3,324	12	40	Medium hard, good structure
17	4 × 12 × 12. Soft shale	9·83	10·45	11·85	0·83	0·88	1,174	3,849	O.K.	O.K.	Medium hard, good structure
18	4 × 12 × 12	5·58	6·83	8·22	0·67	0·83	876	2,934	O.K.	O.K.	Hard, fair structure
19	4 × 12 × 12	6·15	7·13	8·67	0·61	0·78	1,128	3,919	29	48	Medium hard, fair structure
20	4 × 12 × 12. Surface clay	14·60	15·50	17·40	0·84	0·89	915	2,299	50	50	Fair structure
21	8 × 5 × 12. Clay and shale, speed tile	6·31	7·34	8·85	0·71	0·83	2,166	5,014	O.K.	O.K.	Medium hard
22	8 × 5 × 12. Shale, speed tile	4·68	5·05	6·64	0·70	0·76	2,821	7,518	O.K.	O.K.	Hard
23	8 × 5 × 12. Clay and shale, speed tile	13·65	14·20	15·64	0·87	0·91	2,404	6,259	O.K.	O.K.	Medium hard
24	8 × 5 × 12. Speed tile	4·68	5·75	7·74	0·61	0·74	2,835	6,961	O.K.	O.K.	Hard, fair structure

25	8 × 5 × 12. Speed tile	1·76	2·73	3·95	0·44	0·68	2,885	6,992	O.K.	O.K.	Hard, fair structure
26	4 × 8 × 12, 2-cell. Buff-burning, high-lime surface clay	23·76	25·97	27·64	0·86	0·94	600	1,880	3	25	Very soft
27	4 × 8 × 12, 2-cell. Surface clay	9·27	10·21	13·50	0·66	0·73	843	2,644	O.K.	O.K.	Medium hard, fair structure
28	4 × 8 × 12, 2-cell. Surface clay	20·21	21·20	25·41	0·80	0·84	728	1,770	8	35	Soft, porous, made with sawdust
29	4 × 8 × 12, 2-cell. Surface clay	22·60	24·40	27·40	0·83	0·89	592	1,562	.....	.....	Soft
30	4 × 8 × 12, 2-cell. Soft shale and clay	10·40	11·10	15·90	0·65	0·70	986	2,600	.....	.....	Medium hard, good structure, lime pebbles
31	5 × 8 × 12, 2-cell. Surface clay	10·10	11·04	13·70	0·74	0·81	679	2,668	O.K.	O.K.	Medium hard, fair structure
32	5 × 8 × 12, 2-cell. Buff-burning surface clay	20·10	21·80	27·70	0·73	0·79	666	1,977	20	50	Soft, poor structure, stony
33	5 × 8 × 12, 2-cell. Surface clay	18·10	19·00	20·30	0·90	0·94	442	1,744	3	9	Soft
34	5 × 8 × 12, 2-cell. Surface clay	28·50	30·40	33·00	0·87	0·92	390	1,027	6	24	Soft, stony, poor structure
35	5 × 8 × 12, 2-cell. Surface clay	14·10	15·50	18·20	0·77	0·85	757	2,364	40	50	Medium hard, fair structure
36	5 × 8 × 12, 2-cell. Soft shale and clay	8·90	10·00	13·10	0·68	0·76	626	2,172	O.K.	O.K.	Medium hard, good structure, lime pebbles
37	5 × 8 × 12, 2-cell. Soft shale and clay	9·30	10·70	13·80	0·65	0·75	610	2,280	.....	.....	Medium hard, good structure
38	5 × 8 × 12, 3-cell. Surface clay	19·19	20·70	23·29	0·83	0·89	521	2,026	10	40	Medium hard, laminated
39	5 × 8 × 12, 3-cell. Surface clay	16·50	17·85	20·13	0·82	0·89	506	1,731	14	45	Medium hard, laminated
40	5 × 8 × 12, 3-cell. Surface clay	16·22	17·29	19·51	0·83	0·89	571	2,232	20	50	Medium hard

TABLE III—Concluded

Average Results of Determinations of Absorption Properties, Compressive Strength, and Freezing and Thawing

Sample No.	Description and raw material	Absorption data			Absorption ratio		Compressive strength		Freezing and thawing		Remarks
		Per cent absorption									
		5 hours cold	48 hours cold	5 hours boil	C_5/B_5	C_{48}/B_5	Gross area, lb./sq. in.	Net area, lb./sq. in.	Initial failure, cycle No.	Final failure, cycle No.	
41	5 × 8 × 12, 3-cell. Surface clay	9·80	10·70	13·31	0·74	0·80	717	2,648	O.K.	O.K.	Medium hard, good structure
42	5 × 8 × 12, 3-cell. Surface clay	14·46	15·96	18·76	0·76	0·84	415	1,639	10	25	Medium hard, laminated
43	5 × 8 × 12, 3-cell. Soft shale	7·40	7·95	8·81	0·83	0·89	1,351	4,846	.....	.....	Hard, fair structure
44	5 × 8 × 12, 3-cell. Clay	9·90	11·00	13·00	0·76	0·84	667	2,626	O.K.	O.K.	Medium hard, fair structure
45	5 × 8 × 12, 3-cell. Silty surface clay	12·80	13·30	15·40	0·81	0·84	848	2,863	9	35	Soft
46	5 × 8 × 12, 3-cell. Soft shale and clay	7·00	8·50	11·00	0·63	0·77	593	2,548	.....	.....	Fair structure, slightly laminated
47	4 × 8 × 12, 3-cell. Buff-burning, high-lime surface clay	21·38	23·10	24·83	0·86	0·93	982	2,407	10	50	Soft
48	6 × 8 × 12, 3-cell. Surface clay	12·70	13·10	14·60	0·86	0·89	588	2,284	10	25	Medium hard, poor structure, laminated
49	4 × 5 × 12, 2-cell. Surface clay	16·88	17·94	20·90	0·81	0·86	442	1,319	.....	.....	Soft
50	5 × 6 × 12, 2-cell. Soft shale	8·89	9·56	10·55	0·84	0·91	1,055	4,186	.....	.....	Hard, laminated
51	8 × 5 × 12, Special shape. Surface clay	9·17	9·86	12·63	0·72	0·78	942	2,944	O.K.	O.K.	Medium hard, laminated

52	6 × 12 × 12, 3-cell. Surface clay.....	11·78	11·81	13·79	0·80	0·85	978	2,402	.....	.....	Medium hard, good structure
53	8 × 8 × 12, 4-cell. Shale.....	13·18	14·04	15·42	0·86	0·91	1,748	7,414	23	50	Medium hard
54	8 × 8 × 12, speed tile. Clay and shale.....	11·93	12·99	14·66	0·81	0·88	1,634	5,668	O.K.	O.K.	Medium hard
55	8 × 12 × 12, 6-cell. Soft shale and clay.....	10·50	12·10	15·00	0·72	0·81	579	3,610	.....	.....	Medium hard, fair structure, laminated
56	Interlocking tile. Surface clay.....	11·09	11·81	13·79	0·80	0·85	978	2,402	O.K.	O.K.	Medium hard, slightly laminated
57	Interlocking tile.....	4·15	5·78	8·55	0·48	0·67	949	2,657	O.K.	O.K.	Hard, good structure
58	Interlocking tile.....	5·48	6·43	8·11	0·67	0·79	1,052	2,856	O.K.	O.K.	Medium hard
59	Interlocking tile. Surface clay.....	22·70	24·20	26·20	0·87	0·93	604	1,476	1	15	Soft

TABLE IV

Individual Results of Freezing and Thawing Tests

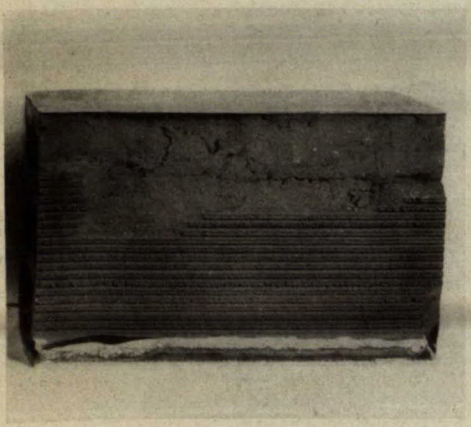
Sample No.	Per cent absorption	C_{48}/B_5 ratio	Number of cycles	Per cent loss of weight, 50 cycles	Sample No.	Per cent absorption	C_{48}/B_5 ratio	Number of cycles	Per cent loss of weight, 50 cycles
25-7	2·1	0·79	50	0·00	23-8	12·7	0·90	50	0·43
4-6	2·5	0·69	50	0·02	11-6	12·8	0·85	50	1·29
18-6	2·6	0·65	50	0·00	23-7	12·8	0·90	50	0·44
19-8	2·6	0·66	50	0·00	56-7	12·8	0·85	50	14·68
25-8	2·7	0·76	50	0·00	16-6	12·8	0·84	50	4·56
25-6	3·9	0·74	50	0·00	48-6	12·8	0·88	50	4·42
57-8	4·4	0·63	50	0·00	54-7	13·0	0·89	50	1·18
22-7	4·6	0·73	50	0·08	9-8	13·1	0·87	43	F
11-8	4·6	0·64	50	0·25	6-6	13·2	0·88	20	F
22-8	4·9	0·76	50	0·08	4-8	13·4	0·88	50	1·46
56-8	4·9	0·58	50	0·19	12-7	13·5	0·92	40	F
57-6	4·9	0·61	50	0·00	6-8	13·6	0·89	28	F
57-7	5·1	0·64	50	0·00	54-6	13·6	0·90	50	0·48
22-6	5·8	0·83	50	0·10	48-7	13·7	0·88	27	F
24-7	5·9	0·74	50	0·00	6-7	13·9	0·90	26	F
24-8	6·1	0·77	50	0·00	20-4	14·0	0·89	50	1·03
45-6	6·1	0·74	50	0·13	35-4	14·0	0·78	50	2·56
10-8	6·4	0·87	50	0·22	35-5	14·2	0·81	50	3·15
24-6	6·4	0·76	50	0·12	16-8	14·5	0·86	18	F
58-7	7·0	0·83	50	0·22	16-7	14·6	0·86	40	F
27-7	7·2	0·63	50	0·00	53-8	14·7	0·94	38	F
10-6	7·4	0·84	50	0·30	53-9	14·8	0·93	50	4·25
10-7	7·4	0·87	50	0·27	39-7	14·8	0·86	50	0·00
18-10	7·5	0·84	50	0·14	53-10	15·0	0·92	50	6·14
58-6	7·5	0·86	50	0·31	61-6	15·1	0·83	50	3·21
21-7	7·6	0·86	50	0·46	40-8	15·4	0·87	50	3·95
1-8	7·7	0·77	50	0·08	40-7	15·5	0·87	50	0·58
58-8	7·8	0·83	50	0·36	48-8	15·7	0·95	11	F
60-3	7·8	0·69	50	0·20	20-5	15·8	0·86	50	1·37
13-7	8·1	0·79	50	0·28	5-7	16·2	0·94	29	F
42-6	8·2	0·70	50	0·00	7-7	16·3	0·91	18	F
3-7	8·9	0·87	50	0·70	5-8	16·5	0·93	50	14·90
3-10	9·1	0·92	50	0·72	5-6	16·8	0·92	40	F
27-8	9·2	0·73	50	0·00	33-10	16·8	0·96	8	F
18-11	9·2	0·85	50	0·32	40-6	16·9	0·86	50	1·38
44-7	9·2	0·82	50	0·30	9-6	17·0	0·83	50	0·51
21-6	9·3	0·87	50	0·84	33-6	17·0	0·93	15	F
3-6	9·4	0·92	50	0·69	39-8	17·4	0·87	43	F
21-10	9·4	0·91	50	0·68	7-9	17·5	0·92	4	F
60-1	9·4	0·74	50	0·15	45-10	17·5	0·89	40	F
7-6	9·5	0·86	50	0·05	61-4	17·5	0·92	46	F
36-9	9·7	0·71	50	0·44	45-9	17·9	0·93	36	F
31-6	10·0	0·78	50	0·00	61-5	17·9	0·86	33	F
60-2	10·1	0·75	50	0·33	39-6	18·0	0·89	50	1·52
13-8	10·3	0·83	50	0·45	8-6	18·6	0·93	23	F
51-6	10·4	0·80	50	0·22	38-6	19·6	0·89	50	3·19
19-9	10·4	0·86	46	F	28-7	19·6	0·79	50	14·32
17-8	10·4	0·84	50	0·27	33-9	19·8	0·94	9	F
51-8	10·5	0·76	50	0·00	38-7	20·1	0·89	44	F
44-8	10·5	0·89	50	0·41	47-6	20·3	0·93	50	3·40
36-7	10·5	0·73	50	0·64	42-7	20·3	0·87	50	6·58
13-6	10·6	0·86	50	0·39	42-8	20·6	0·90	13	F
17-6	10·6	0·87	50	0·36	47-8	20·7	0·92	50	2·51
36-6	10·6	0·77	50	0·56	38-8	20·8	0·88	30	F
1-6	10·7	0·85	50	0·17	47-7	21·5	0·91	50	2·50
41-7	10·7	0·75	50	0·26	32-7	21·7	0·74	50	1·85
19-10	10·7	0·88	49	F	28-6	21·8	0·77	36	F
27-6	10·9	0·74	50	0·00	32-6	21·8	0·78	50	1·34
41-6	11·0	0·77	50	0·18	8-8	22·0	0·93	50	5·50
31-8	11·0	0·80	50	0·15	8-7	22·8	0·94	29	F
56-6	11·2	0·83	50	0·44	32-10	23·1	0·75	50	1·26
11-7	11·4	0·83	50	4·34	59-10	23·5	0·92	13	F
9-7	11·5	0·83	50	2·29	59-6	23·8	0·91	22	F
17-7	11·5	0·88	50	0·25	59-8	24·0	0·90	15	F
1-7	11·6	0·86	50	0·15	26-6	24·1	0·92	50	9·88
44-6	11·6	0·88	50	0·68	26-7	24·3	0·93	50	18·75
12-6	11·9	0·90	50	0·78	26-8	24·7	0·92	25	F
4-7	12·2	0·87	50	0·27	28-8	25·9	0·79	35	F
12-8	12·2	0·88	50	14·7	34-7	26·1	0·92	22	F
31-7	12·2	0·81	50	0·21	2-6	26·5	0·72	50	1·85
41-8	12·4	0·80	50	0·13	2-7	26·9	0·76	50	2·74
54-8	12·5	0·87	50	0·68	2-8	26·9	0·76	8	F
51-7	12·6	0·80	50	0·37	34-8	29·0	0·91	24	F
23-6	12·7	0·90	50	0·40	34-10	29·1	0·91	40	F

Note. F indicates failure. Tile showing a loss in weight of 1 per cent or more also indicates failure.

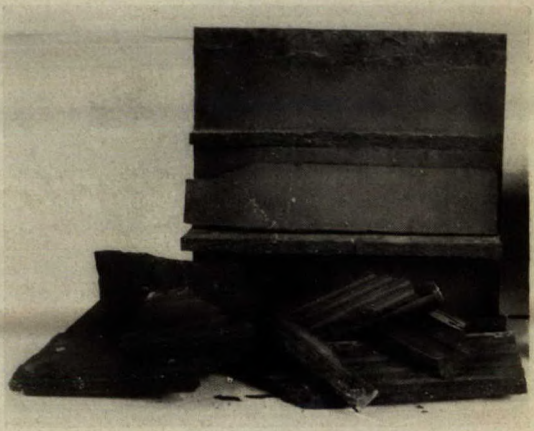
A. Compressive strength: web failure

B. Compressive strength: failure due to shear.

PLATE II

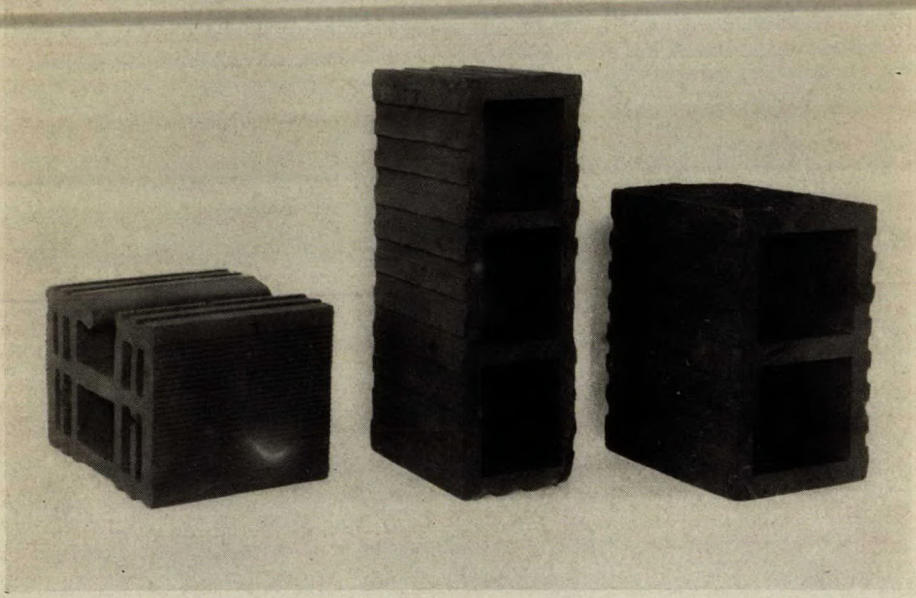


A. Compressive strength: failure due to shear.

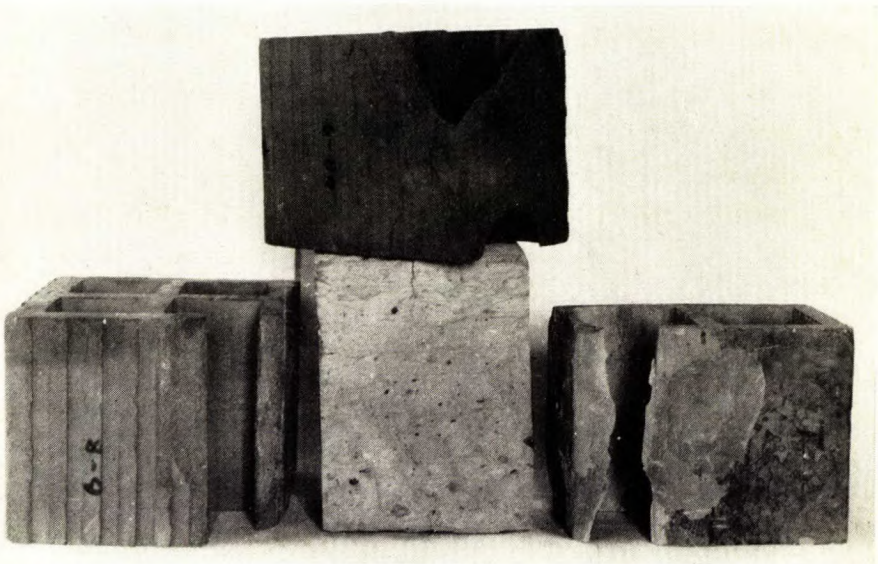


B. Compressive strength: failure by collapse.

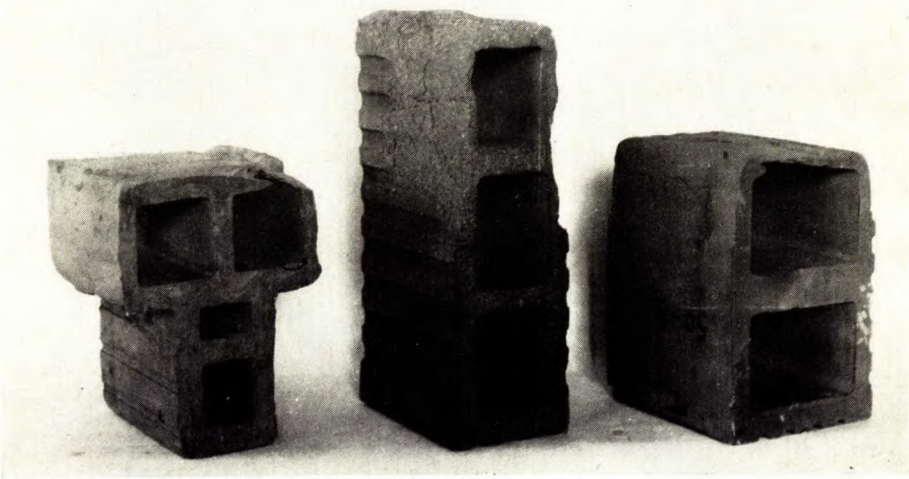
PLATE III



Specimens of tile before freezing and thawing tests.



A. Specimens of tile after freezing and thawing tests: showing examples of failures.



B. Specimens of tile after freezing and thawing tests: showing examples of failures.