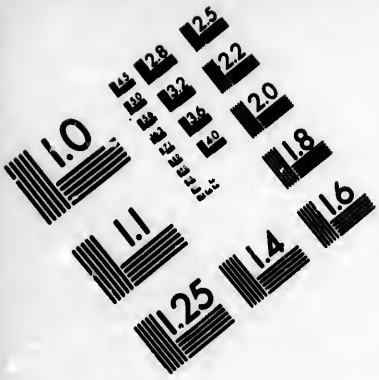


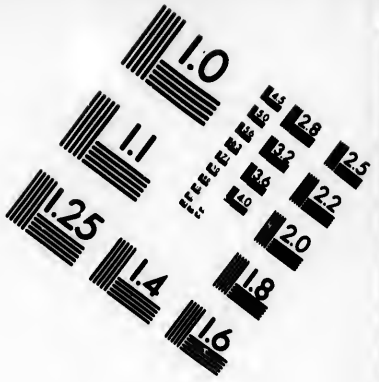


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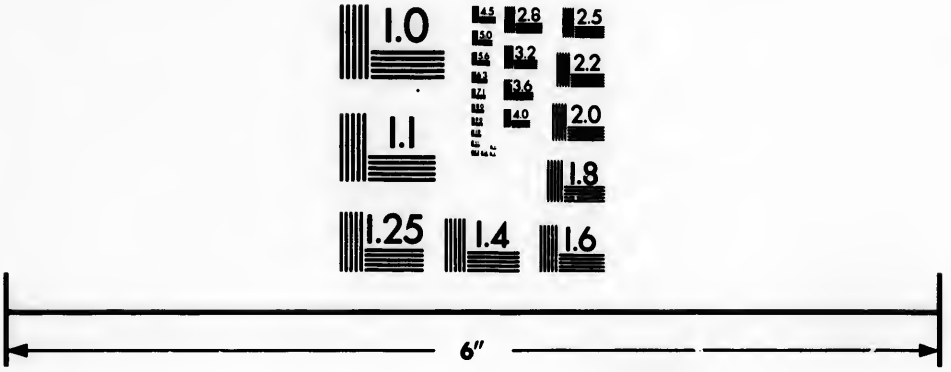



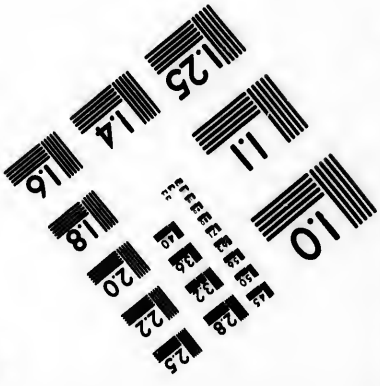


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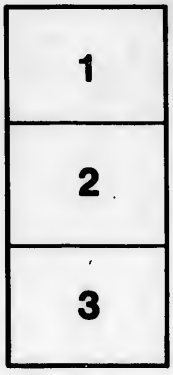


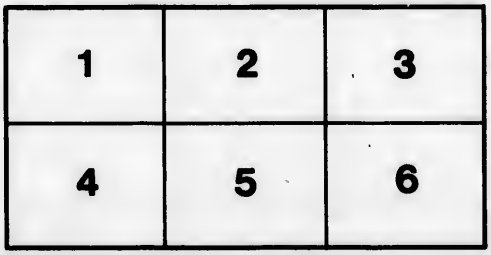


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# CEMENT TESTS.

By Cecil B. Smith, Ma.E., As.M.Can.Soc.C.E.

## PAPER II.

### Frost Tests.

To be read Thursday, 9th January, 1895.

In a previous paper, read before the Society, the writer promised to place before its members the results of certain frost tests, which were being made at that time.

They are now given, in hope that they may be of some interest to those engineers who are contemplating the building of cement mortar masonry, or cement concrete in cold weather.

*Method of procedure.*—The briquettes were all made in the same manner, the 1 to 1 mixtures having 18 per cent. of water, and the 3 to 1 mixtures 15 per cent., being purposely greater than the amount used in ordinary laboratory tests, so as to get the mortar softer, and resembling more closely the condition in which masons use mortar in ordinary construction, as the effect of frost may be greater on soft mortars than on dry ones.

The briquettes were all rammed into the moulds in 3 layers, and the briquettes to be subjected to frost tests were immediately put outside on a window-sill. In a few hours, after the briquettes were frozen hard, they were removed from the moulds, and left exposed on the window-sills for two, three, or four months, care being taken to keep the snow swept off so as to allow the frost to have its full effect.

The tables, given, speak for themselves, and probably each engineer will draw special conclusions of his own, the writer will only mention a few points that seem obvious to him.

#### I. four months tests.

It would appear, from these tests, that it is quite safe to build masonry work in November, in Montreal climate, when the materials are mixed and exposed to the air at about the freezing point. The proportion which the strength of the frost tests bears to the submerged ones is about that which would be obtained under the most favourable circumstances. The briquettes were all firm, smooth, and hard on the surface, and although subjected to 4 months of severe frost in an exposed position, they did not seem to have been at all damaged.

#### II. three months tests.

These were all made in December, and the coldest days were purposely selected. Yet the only briquettes which were blown in pieces were those made from two very inert, slow-setting, poor Canadian natural cements. The two other natural cements (one Canadian, the other Belgian) were quicker setting, and stood the test well. With the Portland cements, the diminution in strength is more apparent than real, the proportion of 90 to 164, which is the average of 11 brands, is really between briquettes $\frac{3}{4}$″ to $\frac{7}{8}$″ square, and briquettes 1″ square, the frost specimens being weathered off.

It is reasonable, however, that a briquette 1″ square, exposed on 3 sides to the direct action of the frost, is rather more severely tested than mortar would be if placed in a wall, even the bottoms of the briquettes resting freely on the stone window-sills were largely uninjured, and the centres of all the briquettes appeared uninjured. As a result of these experiments, the writer would feel perfectly safe in laying cement mortar in December, with Portland or active natural cements, in weather 10° to 15° above zero, and in the most exposed situations, expecting in the spring, to find ¼″ to ½″ disintegrated at exposed joints, and needing re-pointing, or better still, the pointing could be left till spring, and done once for all.

### III. TWO MONTHS TESTS.

These tests were much more severe in their nature, the sand and cement were exposed for hours in the open air, in small quantities, until they were absolutely down to the temperature of the outer air, and in the cold water and salt-water series the water was also exposed, until it was, in three cases, actually below the freezing point, being in a slushy condition.

These materials were put together in the laboratory, as rapidly as possible, and exposed again at once, the usual interval being about 6 minutes, and the actual temperature of the mortar just before exposure having reached about 33° or 34° F., while in the hot water tests the mixture rose, on an average, to 58° or 60°, just before exposure, which was just about laboratory temperature.

The experiments are hardly extensive enough to be fully conclusive, being made only on 7 brands of cement, but they point clearly to the advantage of the use of salt. Those briquettes made with salt showed good strength and little injury; although made with materials, at low temperatures exposed in severe cold, they seemed to be chiefly affected only on the surface.

On the other hand, the use of hot water does not seem to be of any advantage, particularly in Portland cements; a reason advanced by one writer for this fact was, that the bringing together of materials in a mortar, at widely divergent temperatures, exerted a prejudicial effect on the cement, hindering proper crystallization, and that the use of materials at, as nearly as possible, the same temperatures would produce more rapid and stronger action. The effect of hot water on natural cements is not so disappointing, but does not show much increase over the strength of similar specimens made with cold water.

The general result of these experiments, to the writer's mind, points to the idea that in any weather, in winter, not extremely cold, say not lower than + 15° F., masonry work can be laid with cold sand, cold cement and cold water, provided the natural time of set of the cement is not more than 5 or 6 hours, and that by the addition of about 2 or 3 per cent. of salt to the water, the same work may be done in weather down as low as zero, which is as cold as men will work. The disintegration will not extend probably deeper than ¼″ to ½″—the remainder of the mass being quite sound.

By what process cement sets, after it has, in a few minutes, been frozen solid, and remains frozen for months, the writer will leave to others to explain; but set it certainly does, without ever having been thawed out.

## 4 MONTH TESTS.

### BRIQUETTES MADE DURING MONTH OF NOVEMBER, 1894.

| Date of Exposure. | No. of Brand. (See Paper 1.) | Ordinary time of setting. Initial. | Ordinary time of setting. Final. | Mixture. | Temperature at time of mixing. Lab. air | Water. | Materials. | Temp. of outside air. | Time elapsed from mixing to time of exposure. | Tensile Strength. Lab. tests. | Exposed specimens. | *Remarks concerning exposed Specimens.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov. 14th. | 1 | 6°00′ | 12°00′ | 1 to 1 | 59° | 56° | 59° | 36½° | 10′ | 321 | 236 | All these were of natural cements. They were brought in and kept 2 or 3 hours before testing, and allowed to warm so as to drive out the frost, and insure a test not being made on a frozen specimen. There were no external signs of any effect produced by 4 months exposure. |
| | old sample | | | | | | | | | | | |
| Nov. 16th. | 2 | 5°30′ | — | " | 64° | 60° | 64° | 53° | 7′ | 302 | 220 | |
| Nov. 2nd. | 2 | 45′ | 2°45′ | " | 65° | 58° | 60° | 60° | 10′ | 484 | 250 | |
| Nov. 1st. | 15 | 1°00′ | 2°30′ | " | 65° | 62° | 64 | 66° | 10′ | 541 | 237 | |
| | | | Averages | | 63° | 59° | 62° | 51° | 9¼′ | 412 | 236 | |
| Nov. 5th. | 3 | 5°00′ | 20°00′ | 3 to 1 | 68° | 65° | 65° | 37° | 12′ | 143 | 147 | All these were of Portland cement. They were, when necessary, brought into the laboratory and kept there for 2 or 3 hours before being tested, so as to insure that no tests were made on frozen briquettes.<br>No signs of the effect of frost were visible on any of the specimens. |
| Nov. 26th. | 4 | 37′ | 3°10′ | " | 64° | 58° | 57° | 29° | 7′ | 236 | 200 | |
| Nov. 27th. | 5 | 1°00′ | 5°00′ | " | 61° | 62° | 56° | 36° | 9′ | 237 | 183 | |
| Nov. 28th. | 6*a* | 2°00′ | 6°30′ | " | 68° | 64° | 63° | 28° | 8′ | 222 | 128 | |
| Nov. 6th. | 8 | 3°20′ | 6°30′ | " | 63° | 59° | 60° | 42° | 9′ | 172 | 114 | |
| Nov. 9th. | 9 | 13′ | 2°00′ | " | 64° | 57° | 61° | 32° | 11′ | 194 | 182 | |
| Nov. 13th. | 10 | 25′ | 50′ | " | 62° | 57° | 57° | 35° | 7′ | 174 | 176 | |
| Nov. 19th. | 11 | 30′ | 1°0′ | " | 60° | 55° | 57° | 34° | 8′ | 153 | 141 | |
| Nov. 21st. | 12 | 25′ | 3°00′ | " | 61° | 52° | 58° | 39° | 9′ | 119 | 102 | |
| Nov. 20th | 14 | 20′ | 2°30′ | " | 61° | 54° | 58° | 26° | 9′ | 131 | 125 | |
| Nov. 22nd | 19 | 2°40′ | 7°40′ | " | 58° | 54° | 56° | 37° | 7′ | 253 | 387 | |
| | | | Averages | | 62½° | 58° | 61° | 34° | 8⅞′ | 185 | 171 | |

## 3 MONTH TESTS.

### BRIQUETTES MADE DURING THE MONTH OF DECEMBER, 1894.

| Date of Exposure. | No. of Brand. (See Paper 1.) | Ordinary time of setting. | | Mixture. | Temperature at time of mixing. | | | Temp. of outside air. | Time elapsed from mixing to time of exposure. | Tensile Strength. | | *Remarks concerning exposed Specimens.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial. | Final. | | Lab. air. | Water. | Materials. | | | Lab. Test. | Exposed specimens | |
| Dec. | | | | | | | | | | | | |
| 26 | 1 | 6°00′ | 12°00′ | 1 to 1 | 62° | 60° | 58° | + 7° | 5′ | 2-7 | 0 | Briquettes frozen long before set could take place, all blown to pieces by frost. |
| 24 | (old)2 | 5°30′ | ..... | " | 60° | 52° | 53· | +10½° | 7′ | 198 | 0 | ditto |
| 1 | 2 | 45′ | 2°45′ | " | 65° | 60° | 60° | +19½° | 8′ | 190 | 233 | Seemingly quite sound, but broke irregularly as to loads and position of fractures. |
| 1 | 15 | 1°00′ | 2°30′ | " | 61° | 56° | 56° | +16° | 7½′ | 484 | 311 | Practically sound, some slight cracks on the surface. |
| Average of | | No. 2 | & No. | 15 | 63° | 58° | 58° | +18° | 7¾′ | 337 | 272 | |
| Dec. | | | | | | | | | | | | |
| 3 | 3 | 5°00′ | 20°00′ | 3 to 1 | 60° | 60° | 56° | +17° | 7′ | 108 | 101 | About 1-16" on the surface, disintegrated, the remainder quite sound. |
| 31 | 4 | 37′ | 3°10′ | " | 60° | 56° | 56° | +19° | 6′ | 204 | 85 | ditto |
| 31 | 5 | 1°00′ | 5°00′ | " | 48° | 45° | 46° | +14½° | 6′ | 218 | 111 | ditto |
| 31 | 6*a* | 2°00′ | 6°30′ | " | 52° | 48° | 49° | + 8½° | 6½′ | 247 | 47 | Three of these disintegrated for 1-16" on outside, the other two injured to the very centre, average of three being (72). |
| 8 | 8 | 3°20′ | 6°30′ | " | 69° | 63° | 63° | +21° | 6½′ | 191 | 163 | Seemed perfectly sound and solid. |
| 10 | 9 | 13′ | 2°00′ | " | 68° | 64° | 64° | +14° | 8′ | 151 | 113 | These during a warm spell of three days remained quite soft, not setting at all, when tested, they showed a slight weathering on the top surface. |
| 18 | 10 | 25′ | 50′ | " | 57° | 53° | 53° | +18½° | 7½′ | 132 | 154 | Seemed perfectly sound and solid. |
| 27 | 11 | 30′ | 1°00′ | " | 70° | 65° | 65° | + 7° | 7′ | 107 | 59 | Disintegrated for ¼" on top and sides, remainder solid looking. |
| 28 | 12 | 25′ | 3°00′ | " | 61° | 55° | 59° | + 9° | 6′ | 89 | 23 | Disintegrated for ¼" on top and sides, remainder solid looking. |
| 31 | 14 | 20′ | 2°30′ | " | 50° | 50° | 54° | − 7° | 7′ | 131 | 49 | ditto |
| 29 | 19 | 2°40′ | 7°40′ | " | 65° | 61° | 61° | − 6° | 6′ | 223 | 87 | Only 1 briquette was disintegrated on the surface, but all were weak and brittle, crumbling if rubbed with the fingers. |
| | | | Averages | | 60° | 53° | 54° | +10½° | 6¾′ | 164 | 90 | |

## 2 MONTH TESTS.

(With cold water.)

BRIQUETTES MADE DURING THE MONTH OF JANUARY, 1895.

| Date of Exposure. | No. of Brand. (See Paper I.) | Ordinary time of setting. Initial. | Ordinary time of setting. Full. | Mixture. | Temperature at time of mixing. Lab. air. | Temperature at time of mixing. Water. | Temperature at time of mixing. Materials. | Tem. of mix't're just before exposure. | Temp. of outside air. | Time elapsed from mixing to time of exposure. | Tensile Strength. Lab. tests. | Tensile Strength. Exposed specimens | *Remarks concerning exposed Specimens.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. 14 | 2 | 45′ | 2°45′ | 1 to 1 | 61° | 32° | +19° | 40° | +18° | 6′ | 295 | 21 | Practically all blown to pieces, the solid core of two briquettes giving 105 lbs. = 21 lbs. average. |
| 5 | 15 | 1°00′ | 2°30′ | " | 57° | 36° | +26° | 38° | − 3° | 6′ | 330 | 87 | All the exterior blown to pieces, but'r solid |
| | | | Averages | | 59° | 34° | +22½° | 39° | + 7½° | 6′ | 312 | 54 | |
| Jan. 21 | 3 | 5°00′ | 20°00′ | 3 to 1 | 63° | 32° | +14° | 34° | +13° | 6½′ | 86 | 0 | All soft and crumbling. No strength at all. |
| 24 | 8 | 3°20′ | 6°30′ | " | 57° | 32° | + 5° | 36° | + 5° | 9′ | 214 | 5 | Cem. frozen when mixed 6′ mixed by hand.a very severe test; briquettes appeared firm on surface, but crumbled when touched. |
| 29 | 9 | 13′ | 2°00′ | " | 60° | 32° | +20° | 37° | +18° | 6½′ | 133 | 92 | Disintegrated on top for 1-16″; remainder solid. |
| Feb. 5 | 10 | 25′ | 50′ | " | 55° | 34° | −11° | 30° | −11° | 6′ | 145 | 39 | This mortar frozen when mixed, mixed by hand on table, a very severe test, briquettes appeared firm on surface, but weakened all through. |
| | | | Averages | | 59° | 32½° | + 7° | 34° | + 6° | 7′ | 144 | 34 | |
| | Average of | | Nos. 3, 8 and 9 | | 60° | 32° | +13° | 36° | +12° | 7′ | 144 | 32 | |

## 2 MONTH TESTS.

(With hot water.)

## BRIQUETTES MADE DURING THE MONTH OF JANUARY, 1895.

| Date of Exposure. | No. of Brand. (See Paper 1.) | Ordinary time of setting. Initial. | Ordinary time of setting. Final. | Mixture. | Temperature at time of mixing. Lab. air. | Temperature at time of mixing. Water. | Temperature at time of mixing. Materials. | Tem. of mixt're just before exposure. | Temp. of outside air. | Time elapsed from mixing to time of exposure. | Tensile Strength. Lab. tests. | Tensile Strength. Exposed specimens | *Remarks on exposed Specimens.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. 18 | 2 | 45′ | 2°45′ | 1 to 1 | 64° | 125° | 35° | 68° | +11° | 6′ | 428 | 109 | Badly blown on exterior for ¼", but interior still solid. |
| 5 | 15 | 1°00′ | 2°30′ | " | 57 | 126° | 30° | 65° | + 3° | 6′ | 250 | 23 | Top surface blown off for ½", interior solid looking. |
| | | | Averages | | 60½° | 125½ | 32½° | 66½° | + 7° | 6′ | 339 | 66 | |
| Jan. 21 | 3 | 5°00′ | 20°0′ | 3 to 1 | 63° | 125° | 18° | 61° | +15° | 6′ | 85 | 0 | All soft and crumbling, no consistency at all, |
| 23 | 8 | 3°20′ | 6°30′ | " | 64 | 110° | 20° | 59° | +20 | 6½′ | 99 | 47 | Set very slowly in laboratory, those exposed were neither frozen nor set after 4 hours. |
| 30 | 9 | 13′ | 2°00′ | " | 63° | 119° | 18° | 59° | +18° | 5½′ | 109 | 88 | Disintegrated for about ½" on top, remainder solid. |
| Feb 5 | 10 | 25′ | 50′ | " | 55° | 115° | −11° | 54° | −11° | 7′ | 132 | 21 | Slightly disintegrated on top, and weakened all through. |
| | | | Averages | | 61° | 117° | +11° | 58° | +10½° | 6′ | 106 | 39 | |
| | Average of Nos. 3, 8 and 9 | | | | 64 | 118° | +19° | 60° | +18° | 6′ | 98 | 45 | |

## 2 MONTH TESTS.

(With 2 per cent. of salt in the water.)

BRIQUETTES MADE DURING THE MONTH OF JANUARY, 1895.

| Date of Exposure. | No. of Brand. (See Paper 14) | Ordinary time of setting. | | Mixture. | Temperature at time of mixing. | | | Tem. of mix't're just before exposure. | Temp. of outside air. | Time elapsed from mixing to time of exposure. | Tensile Strength. | | Remarks on exposed Specimens. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial. | Full. | | Lab. air. | Water. | Materials. | | | | Lab. test. | Exposed specimens | |
| Jan. 18 | 2 | 45′ | 2′45″ | 1 to 1 | 64° | 32° | 22° | 41° | 11° | 6′ | 320 | 73 | Blown on surface for about ¼", interior solid. |
| 9 | 15 | 1°00′ | 2°30′ | " | 58° | 40° | 9° | 42° | 9° | 6′ | 280 | 143 | Slightly blown on bottom, other fine cracks on top, otherwise solid. |
| | | | Averages | | 61° | 36° | 15½° | 41½° | +10° | 6′ | 300 | 108 | |
| Jan. 21 | 3 | 5°00′ | 20°00′ | 3 to 1 | 65° | 29° | 25° | 39° | 25° | 6′ | 101 | 39 | Exterior worn with loose sand, but interior hard and firm. water was slushy at time of mixing. |
| 28 | 8 | 3°20′ | 6° 30′ | " | 56° | 30° | 13° | 30° | 12° | 6½′ | 183 | 224 | In perfect condition, water was slushy at time of mixing. |
| 31 | 9 | 13′ | 2°00′ | " | 57° | 30° | 17° | 30° | 19° | 6′ | 105 | 92 | One briquette badly affected, and others quite sound. |
| | Average of (3) | | | | 59° | 30° | 18° | 33° | 17° | 6′ | 130 | 118 | No. 10 is not tested. |

NOTE.—Each test recorded in this table is the average of 5 briquettes, all briquettes rammed moderately, in 3 layers, with an iron hammer having ½" square end, and weighing about ½ lb.