

THE ACTION OF FROST ON CEMENT AND CEMENT MORTAR, TOGETHER WITH OTHER EXPERIMENTS ON THESE MATERIALS.*

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This paper describes in detail a series of experiments, extending over the past two years, made by the writers, in order to ascertain:—

The effects of frost, and alternate frost and thaw, on the tensile strength of cement and cement mortar when mixed with—

- (a) fresh water, cold or warm;
- (b) sea-water;

The temperature below which it is detrimental to mix Portland cement concrete;

The effects produced by immersing concrete in—

- (a) fresh water, hard or soft,
- (b) sea-water;

Absorption of water by (dry) cement;

Quantity of water required to be added to cement to produce complete hardening.

The results of these experiments are not only interesting, but should prove of value to engineers generally.

The Hull Cold Storage Company, of Hull, England, kindly allowed the writers to use its refrigerating rooms in order to obtain the degrees of frost necessary for these experiments. The cement used was that manufactured by Robson's Cement Company, of Hull, and all the experiments were carried out at the laboratories of that firm, in Hull, these being kindly placed at the disposal of the writers.

Cement Used in Experiments.

The particulars of the cement used are as follows: Made on January 28th, 1907. Residues on a 5776-sieve (that is, having 76 meshes per linear inch) = 0.5%; residues on a 10,000-sieve (having 100 meshes per linear inch) = 2.0%; residues on a 32400-sieve (having 180 meshes per linear inch) = 11.5% (showing that the cement was ground extremely fine). Specific gravity = 3.112; flour = 54.5%; Le Châtelier tests, expansion = 2.7 mm.; Faija bath test, cement pat sound and hard; time of set of neat cement with 25% water: Initial set = 35 min.; permanent set = 6 hours, in a room kept at a temperature of 60° Fahr.

Tensile Strains. Neat Cement.

7 days = 685 lb. per sq. in. British Standard Test, 400 lb. per sq. in.

14 days = 787 lb. per sq. in.

28 days = 875 lb. per sq. in. British Standard Test, 500 lb. per sq. in.

It will be seen that these results are well above the British Standard Tests.

Tensile Strains. One Part Cement and Three Parts Sand.

Mixed with three parts by measure of sand, and with no hammering of briquettes into moulds, its mean strength was:—

7 days = 200 lb. per sq. in. British Standard Test, 120 lb. per sq. in.

14 days = 277 lb. per sq. in.

28 days = 333 lb. per sq. in. British Standard Test, 225 lb. per sq. in.

Chemical Analysis.

	Percentage
Insoluble Residue	0.82
Silica	20.43
Alumina	9.10
Oxide of iron	1.95
Lime	62.65
Magnesia	1.25
Sulphuric anhydride	1.38
Loss on ignition	1.66
Alkalies and loss	0.76
	100.00

The sea-water used in these experiments was taken from the North Sea; the fresh water was drawn from the Hull Corporation mains. To obtain the soft water, the temporary hardness of this water was removed, the permanent hardness being from 3 to 4 degrees.

The experiments herein will be compared with the tests just given, which will be referred to as the "Normal Test."

Effects of Frost.

The effects of frost, and alternate frosts and thaw, on the tensile strength of cement and cement mortar when mixed with (a) fresh water—cold or warm, (b) sea-water; and the temperature below which it is detrimental to mix Portland cement concrete, were determined by the following experiments:

Experiment A.—In this experiment the writer set out to discover the weakening effect, upon freshly mixed cement, of continuous light frost, temperature 29° Fahr., and of heavy frost, 15° Fahr. Nine briquettes were made with neat cement, 20 per cent. water, in the laboratory, the temperature of the air being 60° Fahr. These were taken from the moulds 24 hours after gauging and placed in cold stores, temperature 29° Fahr., and were broken at seven and twenty-eight days, respectively, the average tensile strength being:

At 7 days = 610 lb. per square inch.

At 28 days = 905 lb. per square inch.

These results are compared with the normal tests as follows:

Tensile strength in pounds per square inch.

	Normal tests, 24 hours in air at 60° Fahr., in water remainder of time.	In air at 60° Fahr. for 24 hours then 29° Fahr. for remainder of time.
7 days	685	610
28 days	875	905

In the 7 days' test it will be observed that there is a decrease of 10.9 per cent. in tensile strength, and an increase of 3.4 per cent. in the 28 days' test.

Experiment B.—Nine briquettes, made in the same manner as in Experiment A, were placed at 60° Fahr. Three were taken out at the end of 2 days, and placed in cold storage for 25 days; three more, at 7 days, for 21 days, and the other three, at 14 days, for 14 days. All were broken at 28 days, the result being as follows:

Tensile strength in pounds per square inch.

	Normal test in air, 60° Fahr. for 24 hours, then in water.	In water at 60° Fahr. for 2 days, then in air at 29° Fahr.	In water at 60° Fahr. for 7 days, then in air at 29° Fahr.	In water at 60° Fahr. for 14 days, then in air at 29° Fahr.
28 days	875	912	977	942

Experiment C.—Nine briquettes, made as before, were allowed to harden in air for 7 and 28 days at 60° Fahr., the result being:

Average tensile strength at 7 days = 443 lb. per sq. in.

Average tensile strength at 14 days = 525 " "

Average tensile strength at 28 days = 775 " "

* Read before the American Society of Civil Engineers and published in Vol. XXXV., No. 1, Page 1.

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