ACTION OF VARIOUS SUBSTANCES ON MORTAR

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THE following results on the action of various substances on cement mortars were obtained from experiments begun some five or six years ago, and were undertaken to ascertain the action of alkaline waters on concrete, to find out if destructive action really did take place, and also to determine which of these salts ordinarily found in ground water were the cause of such disintegration. The report was published in the form of a paper presented before the convention of the American Society for Testing Materials, at Atlantic City, on June 26th.

The salts usually found in the so-called "alkali waters" of the West are also those which occur in sea-water and are those present in largest amounts in many spring and river waters. They are sodium chloride, magnesium sulphate, calcium sulphate, sodium sulphate and sodium carbonate. In order to test the effect of solutions of these substances on cement mortar, a sample of normal Lehigh Valley cement was selected and from it a large number of sand briquettes were made.

Analysis and tests of the cement are given in Table I.

Table I.—Analysis and Tests of the Cement Employed.

ANALYSIS

Silicia, per cent.	20.20
Oxide of iron, per cent.	2.50
Alumina, per cent.	6.96
Lime, per cent.	62.40
Magnesia, per cent.	3.01
Sulphur trioxide per cent.	1.60
Loss on ignition, per cent.	2.38

PHYSICAL TESTS

Soundness

Steam	O.K.	Cold water	O. K.
Boiling	O. K.	Air	O. K.

Fineness

Passing No. 100	94.3 per cent.
Passing No. 200	77.8 per cent.

Setting Time

Initial set	2 hr., 15 min.
Final set	6 hr., 30 min.

Tensile Strength, lb. per sq. in.

	Neat	Sand
1 day	315	...
7 days	765	245
28 days	875	340
3 months	885	415
6 months	885	435
1 year	890	510

All briquettes were made from a mixture of one part cement and three parts standard Ottawa sand. They were allowed to harden 28 days in air and then immersed in a solution of the salt. The briquettes were piled in such manner that the solution had access to almost their entire surface.

The solutions in all cases except that of the calcium sulphate, which was a saturated solution, were made up of one part of the salt to 100 parts of water, to form practically a 1-per cent. solution. At first the solutions were changed every few days, but after the first month the solutions were changed weekly and after the first year less often. The results obtained are given in Table II.

First it should be remembered that the 28-day strength of briquettes kept in air is much less than that of those kept in water. As will be seen from the results given in Table II., the sulphates have a marked action on concrete, which seems to be most apparent in the case of the magnesium salt. The action of magnesium sulphate on cement mortars has been discussed quite voluminously of late and I will not go into it to any length in this paper

Table II.—Action of Various Salts on Cement Mortars.

Age in Soution	Tensile Strength, lb. per sq. in., after immersion in — Magnesium Sulphate	Magnesium Chloride	Calcium Sulphate	Sodium Sulphate	Sodium Chloride	Sodium Carbonate
0 days†	219	219	219	219	219	219
7 days	268	245	227	257	236	225
28 days	272	300	300	334	268	277
3 months	287	315	334	354	299	324
6 months	196	202	314	378	287	320
1 year	*..	115	209	271	310	337
2 years	...	*..	*...	141	325	360

* Disintegrated.

† The briquettes were aged 28 days in air before immersion.

beyond stating that we carefully analyzed the affected portion and the unaffected portion of a sand briquette which had been stored in a solution of magnesium sulphate. These analyses are given in Table III.

Table III.

	Before Immersion	Unaffected Portion	Affected Portion
Silica, per cent.	75.12	73.96	60.40
Oxide of iron, per cent.	0.52	0.60	0.30
Alumina, per cent.	1.15	1.30	0.64
Lime, per cent.	14.80	14.50	14.21
Magnesia, per cent.	0.70	1.66	3.64
Sulphur trioxide, per cent.	0.33	0.83	5.78
Loss on ignition, per cent.	7.02	7.14	14.97

The large increase in the magnesia and sulphur trioxide and the decrease on the oxides of iron and alumina indicate the elements which react with each other. The loss in silica may be due to chemical action also, but as the surface of the briquettes was very much attacked and the sand grains could be scraped away with the finger, I am inclined to think that the lower silica in the disintegrated portion was probably due to mechanical causes rather than chemical action. It will be noted that in almost all cases the first effect of the solution was to increase the strength of the briquettes and that signs of disintegration in no cases became evident until after a period of three months in the solution.

Some of the briquettes were even boiled in a 5-per cent. solution of magnesium sulphate for several days, and in all cases the briquettes were much stronger after boiling than they were before and fully as strong as briquettes boiled in pure water, showing how slow the action of the sulphates is.

The briquettes which failed were considerably swollen and presented much the appearance of a baked potato which has burst its jacket.

Various authorities have proposed at different times the use of divers ingredients in concrete exposed to sea-water, with a view to their reacting with the salts of the latter to form insoluble compounds which would protect the concrete. Most persistently suggested of these are the salts of barium, which form with soluble sulphates insoluble barium sulphate. I tried both barium chloride and barium carbonate. These were ground very finely and mixed with the cement. I employed 2 per cent. of barium chloride with the cement, and also 2 per cent. and 5 per cent. of barium carbonate. Sand briquettes were made from these mixtures and the test pieces stored in a magnesium sulphate solution containing 10 grams of the salt to the liter. The results are given in Table IV., and, as will be seen, none of these compounds arrest the destruction.