THE HIGH-PRESSURE STEAM TEST OF PORTLAND CEMENTS.

UNSOUNDNESS of a Portland cement, which is evidenced with age by a lack of cohesion and strength, may not be apparent for weeks or months after the cement is hydrated. This fact has created a demand for an accelerated test of soundness, in answer to which a large number of such tests have been proposed. All accelerated tests are designed to hasten the action of any expansive constituents of the cement, producing thereby evidence of unsoundness in a few hours or days.

High-pressure steam as a means of determining soundness apparently was first advocated in 1880 by Dr. Michaelas, who procured a German patent on what he termed a boiling test at higher temperatures in which the cement soundness test pieces were subjected in a steam-tight vessel to steam at 140° C. to 180° C.

Dr. Erdmenger also advocated this test, and in 1881 published a description of his method of testing soundness of cement by means of high-pressure steam. He believed originally that it was the magnesia which caused unsoundness, and that this test detected the presence of magnesia in dangerous quantities. Later, however, he modified this opinion, as he found some cements which contained very little magnesia were unsound when exposed to high-pressure steam, while some cements containing a relatively large percentage of magnesia were found to be sound. For several years thereafter Dr. Erdmenger advocated the use of his high-pressure steam test in which he employed saturated steam at from 3 to 40 atmospheres pressure, and used pats, briquettes, and expansion bars for test pieces at various times.

It is the general opinion that the primary cause of unsoundness in Portland cement is attributable to the presence of free or loosely combined lime. Recent work by Phillips and Klein in confirmation of this opinion reveals additional facts concerning the action of free lime in cement. Their conclusions may be summarized as follows:

Free lime is generally noted in small amounts in well-burned, higher limed cements and in underburned, lower limed cements. On hydration, free lime, according to its fineness, hydrates as crystalline or amorphous calcium hydroxide. The disruption in cements in accelerated tests is due to the formation of the crystalline calcium hydroxide. Calcium hydroxide crystals are found in cement hydrated under normal conditions, but are not as large in size as those found in cement subjected to high-pressure steam.

Since there is no chemical means by which the percentage of free lime in cement can be determined and the identification of this constituent by optical means is difficult and limited, investigators have endeavored to find an economical physical test that would detect the presence of free lime in its dangerous form where it is liable to cause disintegration, cracking, and weakening of the cement.

To effect the quick expansion of the free lime or other expansive constituents, various experimenters have employed heat and water at various temperatures, steam at atmospheric pressure, and steam at pressures from 3 to 40 atmospheres. Accelerated tests may also be divided into qualitative and quantitative tests. In qualitative tests the unsoundness of the cement is exhibited by the development of cracks, the warping of test pieces, or their disintegration. In quantitative tests the amount of expansion of the cement or the effect on the strength of the cement is taken as the measure of the unsoundness.

In 1912 Force recommended the use of a high-pressure steam test and in 1913 issued a specification* for soundness, known as the Force autoclave test.

Several railroads and other corporations adopted this test into their specifications, which brought about considerable controversy between its advocates and the cement manufacturers. Many of the cement manufacturers refused to furnish cement upon a specification which included this test, believing the test to be an abnormal one not in any way measuring the relative soundness or cementing value of Portland cement as used normally in concrete.

The U.S. Bureau of Standards has just issued a report, prepared by R. J. Wig and H. A. Davis, on the value of the high-pressure steam test. The report is the result of an investigation made to establish, if possible, a relationship between the behavior of Portland cements in high-pressure steam and their physical properties under normal conditions of use and exposure, and to determine what value, if any, the high-pressure steam test has as a means of detecting unsoundness which might cause a weakening or disintegration of the cement or concrete.

The test used consists of subjecting an ordinary soundness pat, which has been stored for 24 hours in a damp closet, to a steam pressure of 300 pounds per square inch for at least one hour, the total time in the high-pressure boiler being three hours. A cement was said to pass this test when it exhibited no cracking, warping, or disintegration on examination after the treatment. The quantitative high-pressure steam test consists of molding six briquettes of neat cement at normal consistency, storing these test pieces 24 hours in a damp closet, then subjecting three of them to an atmosphere of steam at 300 pounds pressure for at least one hour; total time in the high-pressure boiler being three hours. The briquettes (both treated and untreated) are then broken in a shot-testing machine. A cement was said to pass this test when the treated briquettes exhibited greater strength than the untreated ones. Throughout this paper cements are classified into three types, respectively: (1) A cement which fails to pass the standard atmospheric steam test; (2) a cement which passes the atmospheric steam test but fails when treated in high-pressure steam; (3) a cement which passes both atmospheric and high-pressure steam tests.

In order to ascertain what proportion of the cements as at present manufactured were sound after exposure in high-pressure steam, all routine samples received for a period of about nine months were subjected to the qualitative high-pressure steam test. Other tests were performed to determine the effect of a small amount of free lime on soundness. A series of mortar and concrete strength tests were made, employing 9 different samples of cement. Tests were also made to determine the linear change occurring in these cements when stored in air, water, or treated in high-pressure steam and also on specimens to the cement in which sand or waterproofing compound had been added.

The following is a general summary of the report:

The general soundness tests show that some cements mixed neat, which are sound according to the standard specification atmospheric steam test and unsound after exposure in high-pressure steam, exhibit signs of unsoundness when stored under normal conditions in dry air. This unsoundness may require nine months or more to develop where the test pieces are of neat cement.

* See *The Canadian Engineer*, September 11, 1913, p. 444.