

ceived, and the finer particles being naturally more absorbent of water and carbonic anhydride than the coarser pieces, it follows that a finely ground cement containing much flour will more rapidly have its original specific gravity reduced by aëration than will a coarsely ground sample, and would thus, falsely, appear to be the more lightly burned of the two.

Standard Sand.—There is a somewhat general idea that tensile or crushing tests of cement with standard sand represent the best results of which the cement is capable. This is erroneous. Sand tests do not give the highest results which can be got out of the cement, but give results which are standardized, and therefore comparable with those obtained by different operators. The crushing strength, especially, of concrete or mortar, depends largely upon the size and character of the aggregate, the absence or presence of dust, clay matter and other things, and the density of the mass. The use of standard sand merely gives results which are comparable, and only represent the strength of a cement when tested under certain conditions and with an aggregate of a definite size and character.

The standard sands employed and specified in different countries vary in size to some extent. These differences in size of grain doubtless have their effect upon the results obtained.

From results obtained by me it appears that the crushing resistance of concrete made from the same cement varies not only with the size, but also with the character of the aggregate.

Autoclave Test.*—This test, recently proposed by Mr. H. T. Force, in charge of testing materials on the Delaware, Lackawanna and Western Railroad, of Scranton, Pa., is merely a revival of Dr. Erdmeyer's high-pressure steam test introduced in Germany about 1881, and rejected by German cement experts as being unreliable and misleading. In the words of Prof. Gary, of the Royal Bureau of Material Testing, it is even less adapted to distinguish useless cements from useful cements than the usual methods of determining constancy of volume. According to Dr. Cushman, of Washington, the details of the test have been several times revised during the last twelve months, but the procedure is now as follows:—

For each test three neat briquettes are made, and after twenty-four hours in a moist closet these are weighed and then placed in the autoclave, sufficient water being added to cover them. Pressure is then raised by heating the apparatus by gas burners or other suitable means, the time taken to raise the pressure to 295 lb. per square inch being not more than one hour.

The pressure is maintained at 20 atmospheres for a further period of one hour, at the end of which time the autoclave is slowly blown off, the briquettes removed (when their condition permits) and placed in the moist closet for one hour. They are then re-weighed and broken in the cement-testing machine in the usual manner. The tensile strength so obtained is compared with that of twenty-four-hour neat briquettes kept in moist air, and must show an increase of at least 25 per cent. over the latter. The autoclave briquettes must also develop a strength of at least 500 lb. per square inch, and the gain in weight must not be greater than 1 per cent. Expansion bars, 1 sq. in. in section and 6 in. long, are

also made up and tested for expansion after twenty-four hours in the moist closet and two hours in the autoclave. The expansion of these bars must not exceed one half of 1 per cent.

Under this test some cements develop greatly increased strength while others were reduced to powder. Comparison of results, extending over twelve months, showed that the failure could not be due to the presence of free lime; but it was thought to be due to the presence of coarse granules of cement which are not hydrated when the cement is gauged, but which might threaten the stability of the structure by subsequent hydration after a lapse of time.

The disruption of the briquettes by the hydration of the coarser particles of cement clinker, under high pressure and heat, is probably correct. I myself drew attention to this in an article published more than six years since, but numerous experiments have convinced me that such coarser particles hydrate eventually in the cold without expansion. If it were otherwise the whole of the concrete work, in this and other countries, carried out with coarsely ground cements during the last twenty years, should now be in a very precarious condition.

I have made a number of tests with the autoclave with somewhat erratic results, but with finely ground modern rotatory cements the Le Châtelier expansion of which did not exceed 2 mm., the whole of the samples, with one exception, conformed to the test as laid down. The one exception, curiously enough, was the most finely ground member of the series, the residue on the 180² sieve being only 1.6 per cent.

On the other hand, a number of samples ground to the fineness stipulated in the standard specification—viz., from 12 to 18 per cent. on the 180² sieve—failed to withstand the conditions of the autoclave test, although they were perfectly sound when tested by the ordinary boiling or Le Châtelier methods.

I hold that growth of strength by age is of less importance and is not such a criterion of quality as is generally considered. Modern cements prepared from purer clinker, and much more finely ground than formerly, attain a strength approximating to the maximum much more quickly, and it is evident that a cement which attains, say, .8 of its maximum strength at short dates has less margin for growth than one which only develops .5 of the maximum in the same time.

The stipulated pressure to be maintained in the autoclave (20 atmospheres) is needlessly high, and serves no useful purpose. The same effect is produced at a pressure of 5 atmospheres as at 20 atmospheres.

There is, therefore, nothing to be gained by carrying out the test at the high pressure advocated in America.

With regard to the utility of such a test, it must first be shown that cements which pass the simpler soundness tests generally employed in this country will yet be dangerous in ordinary work, and secondly, that the autoclave test will detect such cements with certainty. So far neither of these points has been demonstrated.

Free Lime.—No theory connected with Portland cement has obtained a stronger hold, or has attained such hoary antiquity, as the idea that unsoundness of cement is due to free lime locked up within the particles of the ground material. In fact, this theory has been for so long accepted that to question it may possibly be met with derision.

Nevertheless, I confess I have never been a believer in this bugbear, the existence of which has never been demonstrated, although many abortive attempts to do

*See *The Canadian Engineer* for Sept. 11, 1913, (p. 444).