

THE CHEMICAL AND PHYSICAL EXAMINATION OF PORTLAND CEMENT.

(Continued from 15, 181, 1893.)

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NO standard specifications for the testing of Portland cement are required in Great Britain, the determination of fineness, tensile strength and variations in volume, being considered sufficient to determine the value of a cement. The machines for

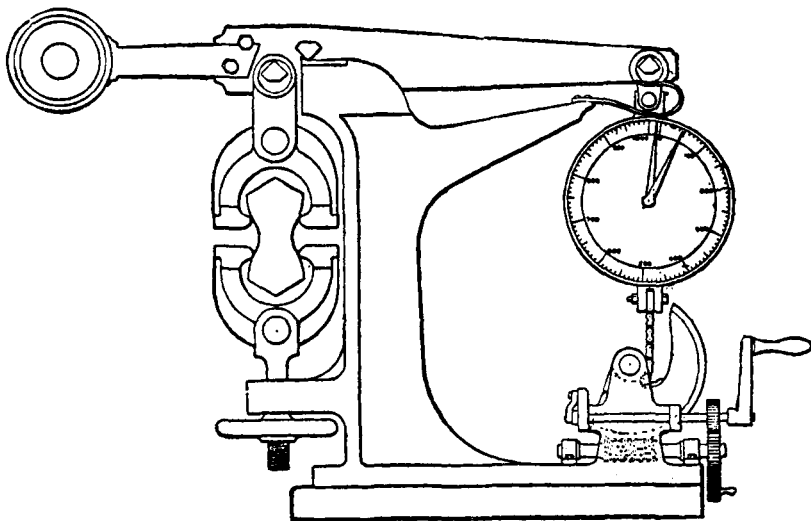


Fig. 5.

tensile strength are the "Faija" (Fig. 5), the "Reid and Bailey" (Figs. 6 and 6a), or the "Grant," the latter described in *Proceedings* of the Institution of Civil Engineers, **62**, 113. The "Reid and Bailey" is essentially the "Michaelis" (Fig. 4), excepting that water is used instead of fine shot for the breaking power.

It is readily seen that the "Faija" and "Grant" machines, not being automatic, require the application of the power at a certain uniform speed to obtain comparable results, since a difference of twenty-five per cent. in tensile strength may be obtained by applying the strain very quickly or very slowly (*Proceedings* of the Institution of Civil Engineers, **75**, 225, 226).

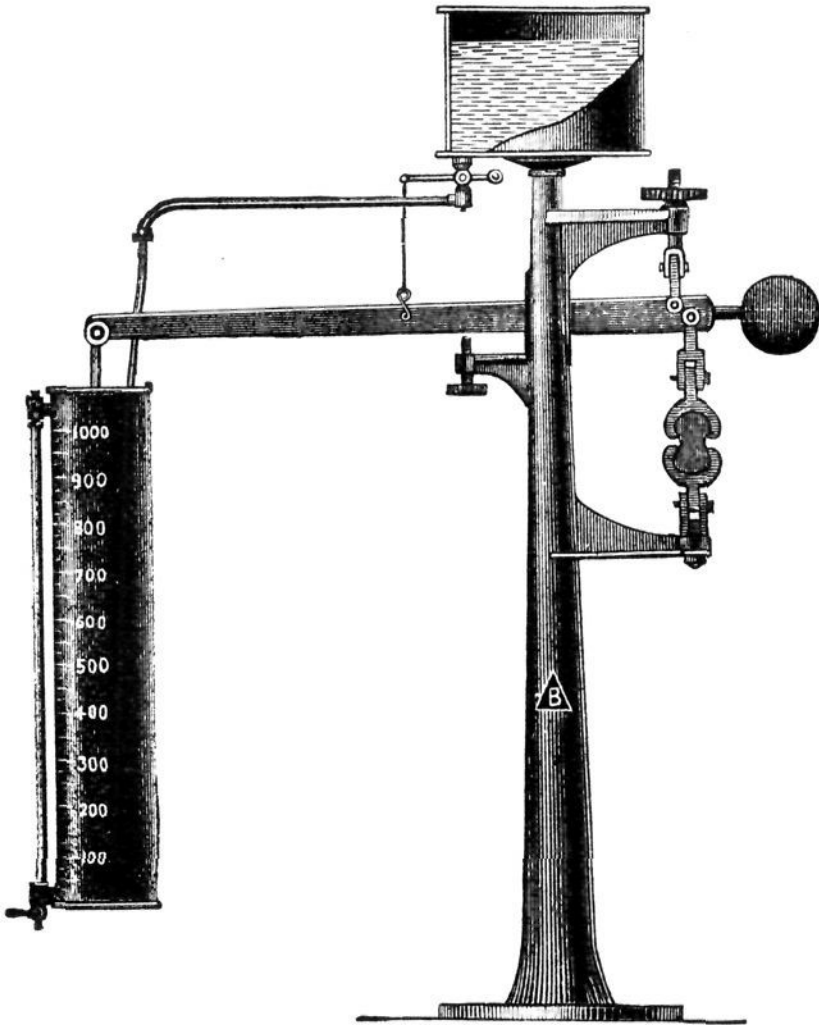


Fig. 6.

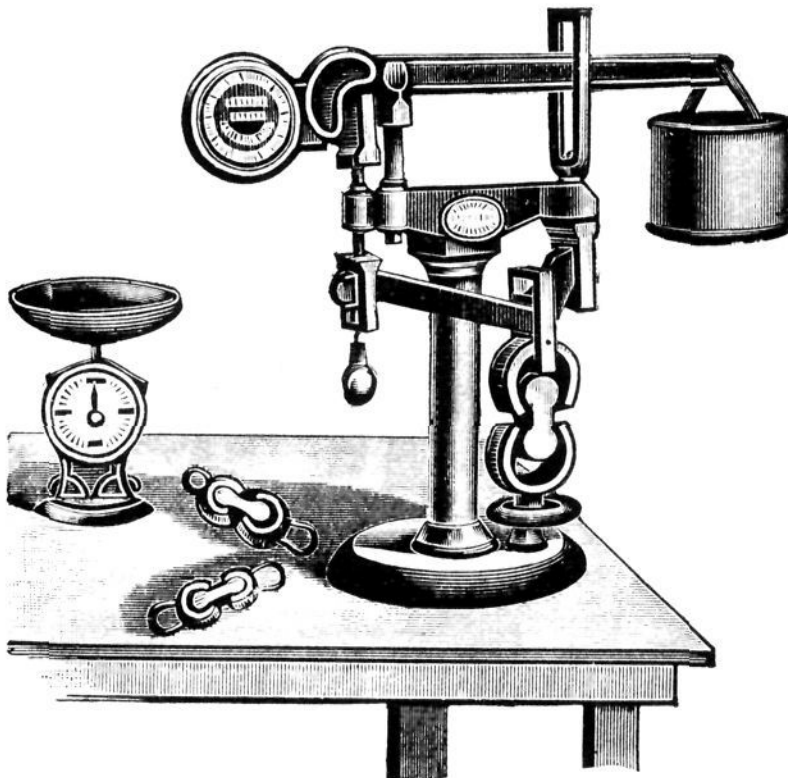


Fig. 6a.

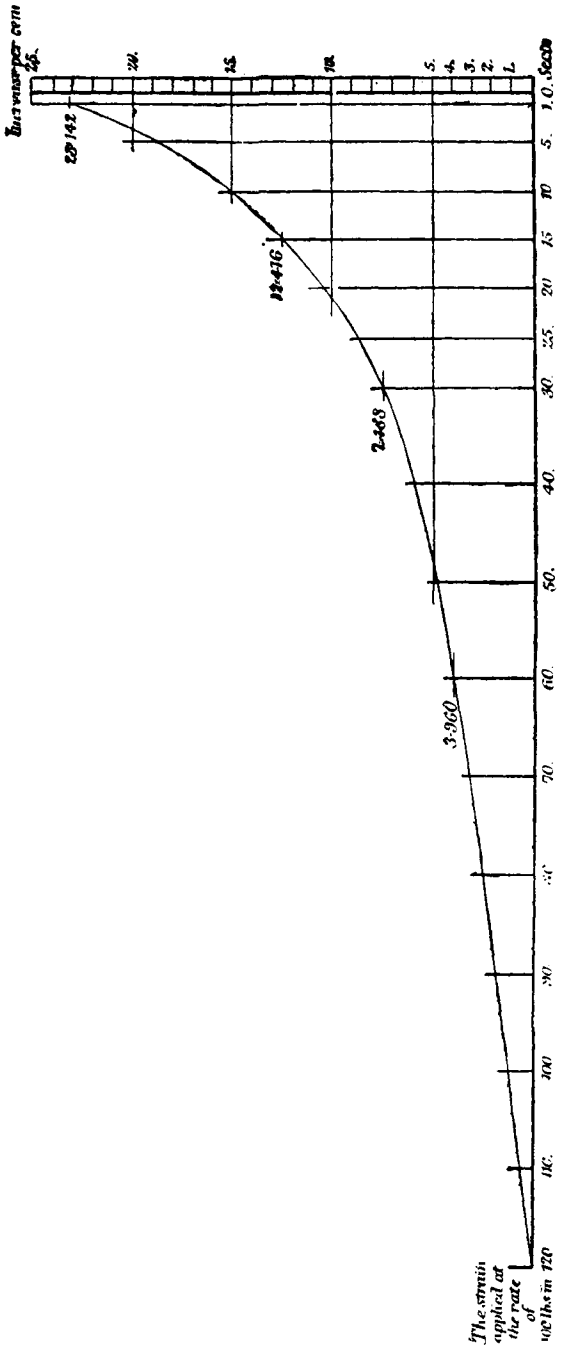


Fig. 7.

Faija has determined this variation with extreme care, the result being indicated in the curve shown in Fig. 7. To overcome these variations a uniform speed of 400 pounds per minute has been accepted as the standard.

Not only are comparable methods required in the use of the machines to obtain uniform results, but the briquettes must also be constructed under similar conditions.

It is manifestly unjust to compare the tensile strength of two cements (even when the briquettes are broken upon the same machine) unless the briquettes have the same weight of water for mixing; the same pressure with the trowel when being formed in the molds, and the same length of time of exposure under water before submitting the briquettes to the tensile strain. Usually the greatest difference is due to the pressure exerted in forming the briquettes.

For instance: Comparing tests made upon the Dyckerhoff Portland cement by Dr. Böhme, Director of the Royal Commission for testing building materials, at Berlin, and by E. J. De Smedt, General Inspector Engineer Department, District of Columbia, we find that the German method gives a much higher tensile strength than the method in use in this country.

DR. BÖHME.		
Age of Briquettes.	Average tensile strength per square inch.	Number of tests.
7 days.....	767 pounds	10
28 "	895 "	10
E. J. DE SMEDT, C. E.		
Age of briquettes.	Average tensile strength per square inch.	
5 days.....	250 pounds	
30 "	700 "	

Showing:

109 pounds increase per day (7 days), Dr. Böhme,
50 " " " " (5 days), De Smedt,

or over 100 per cent. difference upon the same cement.

These variations are undoubtedly due principally to the different pressures upon the cement during the making of the briquettes, and to overcome difficulties of this nature the Vereins deutsche Portland Cement Fabrikanten have modified the rules in the construction of the briquettes so that two methods are acceptable:

First. The normal method, above given, with the trowel, etc., ("Handarbeit").

Second. The use of the Böhme-Hammer apparatus or "machine method," by which the cement in the briquette form

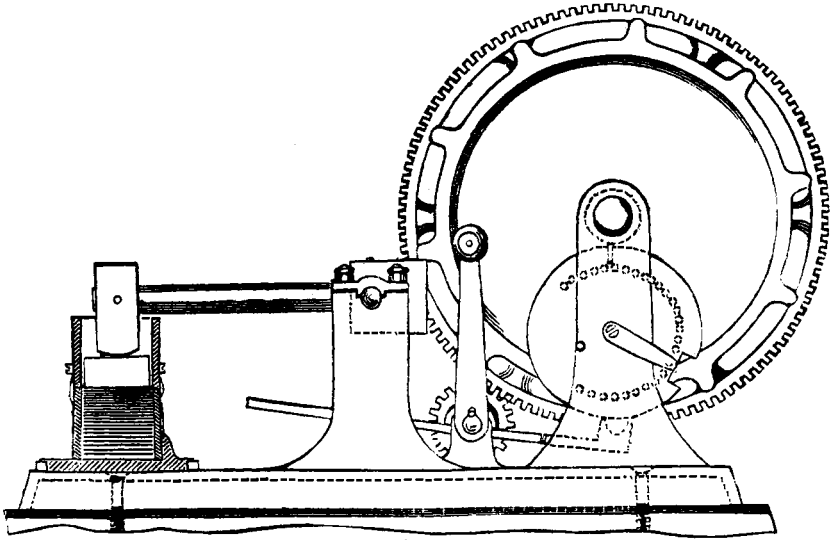


Fig. 8.

(after mixing with proper amount of water), is submitted to a pressure of 150 blows from a hammer weighing two kilos (Fig. 8). The briquette of cement is then removed from the mold and treated for tensile strength as usual.

This subject is receiving considerable attention at the present moment, the evident purpose being to render the tests of tensile strength as uniform as possible by making the working of the apparatus automatic and the production of cement briquettes with the least possible variation in the pressure in the molds.

In this case, no matter how careful the experimenter may be, the "personal equation" enters largely into the results of testing hand-made briquettes, for which reason the manufacture of the briquettes should be as automatic as possible. In no other way can results obtained by different experimenters be compared.

Prof. Charles D. Jameson describes an apparatus for this purpose (Fig. 9). *Transactions of the American Society of Civil Engineers*, **25**, 302.

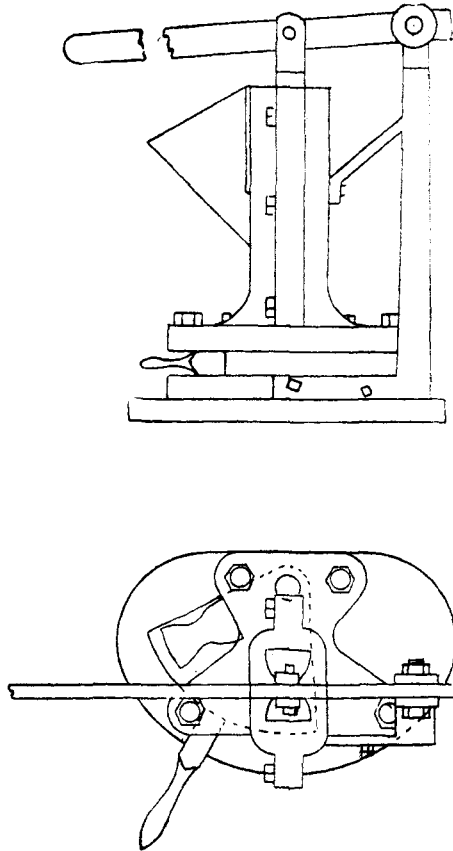


Fig. 9.

The method of operating is as follows: The lever being raised so that the lower end of the piston or main plunger is above the hole in the side of the cylinder communicating with the hopper, cement is put in the hopper and pushed down into the cylinder. The molding plate is pushed against one of the stops, so that one of the openings is beneath the bore of the cylinder. The long lever is forced down, causing the

plunger to force the cement into the opening in the molding plate. After this, the molding plate is swung against the other stop, cutting off the briquette, placing it over the plungers, throwing the other opening in the molding plate directly beneath the cylinder. The smaller lever is lifted, raising the plunger, and forces the briquette out of the mold, after which it is removed. The plunger is then pressed down, the main lever also, the molding plate swung back to the first position, the other plunger lever lifted, and another briquette is ready to be taken away, and so on. After making three briquettes, the main lever is lifted and more cement placed in the cylinder. The machine is best operated by two men, one to feed and operate the long lever, and the other to swing the molding plate, remove the briquettes, and lower the plungers. The pressure on the briquette is 175 pounds per square inch.

The conditions required in France for a good cement are:¹

First. Analysis to determine the chemical composition.

Second. The determination of density.

Third. The determination of fineness.

Fourth. The determination of tensile strength.

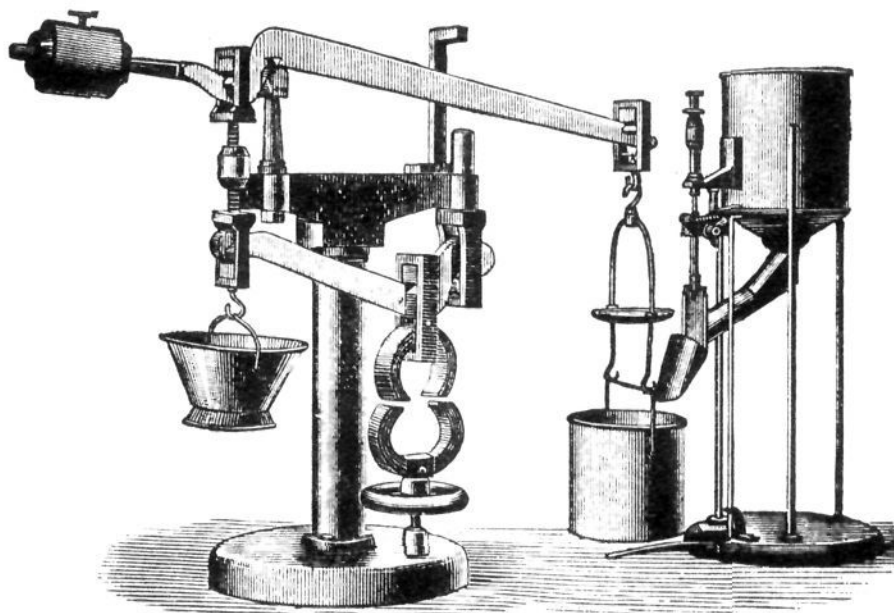


Fig. 10.

Fifth. The determination of crushing strength.

¹ E. Candlot, *Ciments et Chaux Hydrauliques*, Paris, Baudry and Co., 1891.

Sixth. The determination of variations in volume.

The tensile strength is determined by the use of a Michaelis machine, Fig. 10, or the use of a Buignet apparatus, Fig. 11. this latter being upon an entirely different principle than any yet in use, and is thus described by the designer, M. Buignet. Conductor des ponts et chaussées au Havre :

It is composed of a basin A and frame B.

The basin A, filled with mercury and water, closes up by a diaphragm of rubber covered with a metallic disk, and is in direct communication with :

- (a) Manometrique tube D.
- (b) With a movable reservoir R, filled with mercury, by means of a rubber tube T.

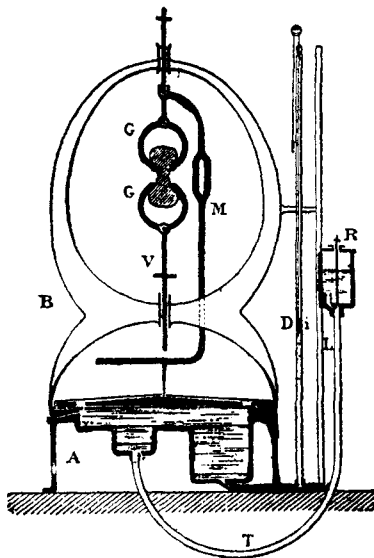


Fig. 11.

The grips G G, in which are to be placed the briquettes to be tested, are fastened, one to the frame B by the support V, the other to the support M, which rests upon the center of the metallic disk over A. It is operated as follows : The briquettes are placed in the grips G G, and the support V moved up or

down until equipoise is established, and then firmly secured by a crank in frame B.

The support M is adjusted until the point at its lower end just touches the metallic disk in A.

By gradually lowering the reservoir R an upward pressure is given to the metallic disk in A, which is transferred to the support M, until when sufficient pressure is exerted the briquette is broken. The moment rupture of the briquette, takes place, the pressure required to do this is indicated by the float *i* in the manometer tube D.

Another instrument made use of to determine tensile strength, and used at l' ecole des ponts et chaussées, Paris, is shown in Fig. 12.

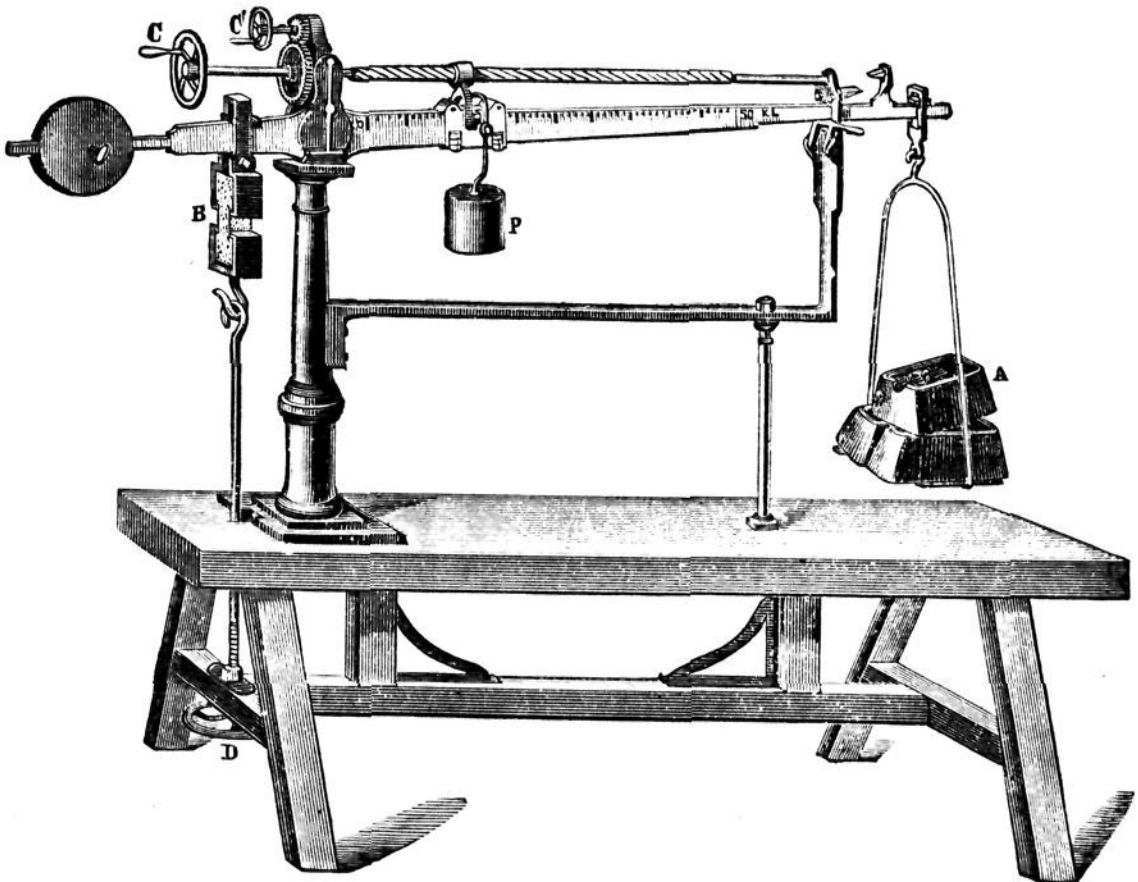


Fig. 12.

It is similar in principle to the Riehle machine (Fig. 2), and the Grant machine (*Proceedings of the Institution of Civil Engineers*, 62, 98).

By a comparison of the various machines used in Germany, England, France, and the United States, we find practically but two in general use. The "Michaclis" (Figs. 4, 10, and 11), and the "Grant" (Figs. 2 and 12). While nearly all engineers require cements to be subjected to the tensile strength test, in fact relying more upon this one test than any of the others, it might be well to include here the opinion of H. Le Chatelier, professor at the École des Mines, Paris, France, as given in a paper presented at the last meeting of the American Institute of Mining Engineers, August, 1893, entitled "Tests of Hydraulic Materials," p. 44.

"The method of tension is at present most widely used, but the preference for it is not well founded.

"Here, as in rupture by bending, only the *surface* of the briquettes acts in a really useful way, and its inevitable irregularities and alterations so greatly affect the precision of the results that they can in no case be trusted nearer than about twenty per cent.

"This preponderant influence of the superficial parts was first shown by the fact that the resistance of briquettes of different sizes increases, not with the section, but, on the contrary, with the perimeter. Finally, M. Durand-Claye has shown that the interior of a briquette may be removed without notably diminishing its resistance to rupture by tension, and has given a complete theoretical explanation of the phenomena which seemed at first sight paradoxical."

THE CRUSHING TEST.

This test is not official in this country and is seldom required by our engineers, who, however, have confined their experiments in this direction mainly to crushing tests of concrete, formed by mixing Portland cement, sand, and broken stone.

Tests upon cubes of neat cement and of mortar composed of one part cement and three of standard sand, are generally included in reports given upon the examination of cements in Europe, the ratio being that the crushing strength is about ten times greater than the tensile strength.

Thus, a cement of good quality should show the following resistances per square centimeter:

TENSILE STRENGTH.

	7 days.	28 days.
Neat cement	25 kilos	35 kilos
1 part cement)	10 "	18 "
3 parts sand)		

CRUSHING STRENGTH.

	7 days.	28 days.
Neat cement	250 kilos	350 kilos
1 part cement)	100 "	180 "
3 parts sand)		

To convert kilos per square centimeter to pounds per square inch, the equivalents used are: one kilo = 2.204 pounds English; 6.451 square centimeters = one square inch English.

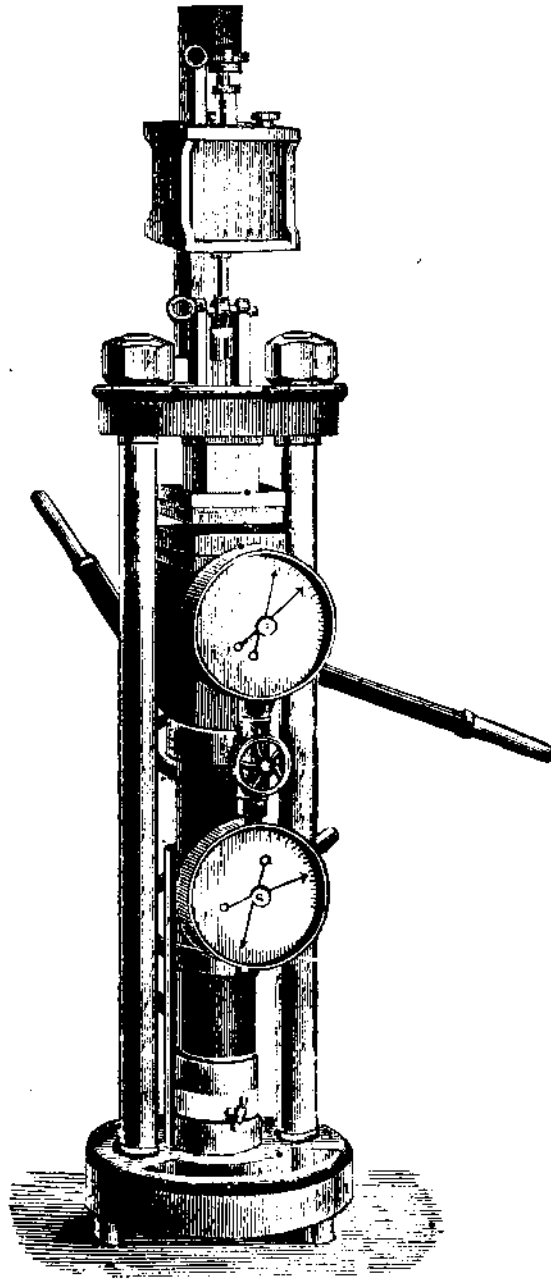


Fig. 14.

The hydraulic presses made use of for this purpose, a few years since, gave very discordant results, as it was impossible to distribute the pressure evenly over the surface of the cubes. This has been overcome, and there are now four machines upon the market whose results are comparable, *viz.* :

The "Suchier," Fig. 14; the "Böhme," Fig. 15; the "Tetmajer," as improved by Prof. Amsler-Laffon,¹ and the "Brink and Hubner."²

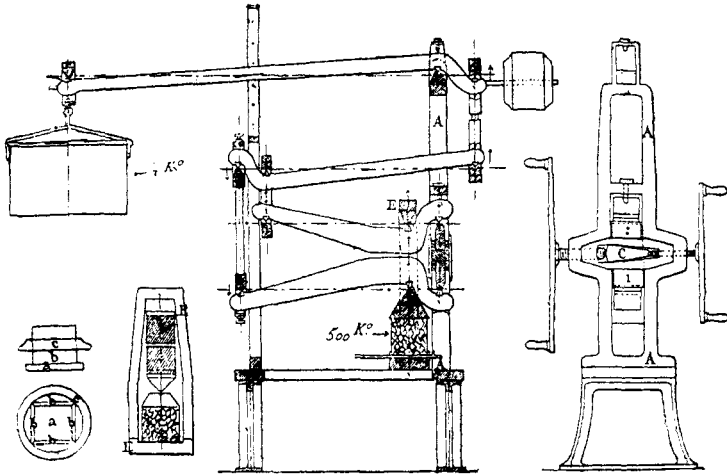


Fig. 15.

Variation in volume (expansion or contraction).—The method of Faija³ the one generally used for this purpose is as follows :

Three pats should be made on pieces of glass or other non-porous substance, and their behavior watched under the following conditions :

Pat No. 1 may be left in the air, and No. 2 should be put in water as soon as it is set hard.

Pat No. 3 should be treated in the apparatus for determining

¹ Consult : *Schweizer Bauzeit.*, January 12, 1889.

² Description of the "Suchier," "Böhme," and "Brink and Hubner" machines will be found in *Der Portland Cement und seine Anwendungen im Bauwesen*, Berlin, 1892.

³ The determination of liability to "checking" or "cracking" (variation in volume) in Portland cements as recommended by *American Society Civil Engineers*, is not as complete as Faija's method, see this JOURNAL, 15, 184.

the soundness of cement. The apparatus consists of a covered vessel in which water is maintained at an even temperature of 110° C; the space above the water is therefore filled with the vapor rising therefrom, and is at a temperature of about 100° C. Immediately the pat is gauged, it should be placed on a rack in the upper part of the vessel, and in five or six hours it may be placed in the warm water and left therein for nineteen or twenty hours. If, at the end of that period, the pat is still fast to the glass and shows no signs of blowing, the cement may be considered perfectly sound; should, however, any signs of blowing appear, the cement should be laid out in a thin layer for a day or two, and a second pat made and treated in the same manner, as the blowing tendency may only be due to the extreme newness of the cement.

If pat No. 3 shows the cement to be unsound, pats No. 1 and 2 will eventually prove it, but it may be weeks or even months before they develop the characteristics. If pat No. 2 blows, it may be because it was put in the water before it was set. A cement is considered set hard when it can no longer be marked by the pressure of the thumb nail.

Résumé:

The determination of the value of Portland cement therefore requires the following tests:

First. Chemical analysis.

Second. Determination of fineness.

Third. Determination of tensile strength, including the use of automatic briquette machines as well as an apparatus for mixing the cement with water, as "Faija" mixing machine.

Fourth. Determination of crushing strength.

Fifth. Determination of variation of volume.