PORTLAND CEMENT.

HISTORY—USES—COMPOSITION—PROCESS OF MANUFACTURE—METHODS OF TESTING, ETC.

By W. S. Blatchley.

A *cement* is any material which is capable of solidifying when in contact with water, without change of volume or notable evolution of heat. It differs from a *lime* in that the latter expands, crumbles and gives off heat when exposed to water. The presence of a clay more or less intimately mixed with a lime checks or stops the crumbling and evolution of heat, and brings about that hydraulicity, or power of slowly solidifying in water which characterizes a cement.

Natural Rock Cement.—If the lime and clay are mixed by nature; that is, if they occur already mixed in a stone which requires only quarrying, burning and grinding to form a cement ready for use, such a cement is termed a "Natural Rock Cement." The first cement of this kind made in the United States was in 1823 from a water lime-rock in Ulster County, New York. The hydraulic properties of this rock were discovered by accident. A canal was being constructed, and it was noticed that the lime which was burned from some of the strata hardened under water instead of slaking. Similar discoveries followed rapidly at other localities, and, as a result, the burning of natural rock cements soon became an industry of prominence. The stone from which this cement is made is termed water limestone, or hydraulic limestone. Vast beds of this stone, excellent in quality, occur in Clark, Floyd and other counties of Indiana bordering the Ohio River. In 1899 the total production of Natural Rock Cement in the United States was 9,868,179 barrels. Of this amount Indiana produced 2,922,453 barrels, valued at $1,022,858, or almost six times as much as any other State except New York, where the production was 4,689,167 barrels. A full account of the growth of the Natural Rock Cement industry in this State, with details and statistics of manufacture, is given by Mr. C. E. Siebenthal in a subsequent paper in this volume.

PORTLAND CEMENT.—Where the materials or ingredients (lime and clay) entering into the cement are mixed artificially, then burned and ground, the resulting cement is termed Portland cement. This artificial cement was first made at Leeds, England, in 1824, by Joseph Aspdin, a bricklayer. He chose the name "Portland Cement" on account of the fancied resemblance in color and texture of the cement, when hardened, to the well-known oölitic building stone of Portland, England. Aspdin took out a patent for this cement, under date of October 21, 1824. His specification is for "An Improvement in the Modes of Producing an Artificial Stone," and is described as follows: "My method of making a cement or artificial stone for stuccoing buildings, waterworks, cisterns or any other purpose to which it may be applicable (and which I call Portland cement) is as follows: I take a specific quantity of limestone, such as that generally used for making or repairing roads, after it is reduced to a puddle or powder; but if I can not procure a sufficient quantity of the above from the roads, I obtain the limestone itself and I cause the puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay, and mix them with water to a state approaching impalpability, either by manual labor or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to a limekiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar and thus applied to the purposes wanted."

It is difficult to recognize in this description a process likely to result in the formation of a cement of the present Portland type. It must be remembered, however, that Aspdin had a hard mountain limestone to deal with, and that probably the most easy way to obtain this material in a state of fine subdivision, in order to mix it with the clay, was to calcine it. It could then readily be slaked and reduced to powder. The next step was to temper it with the requisite amount of clay, and finally the mixture was submitted to a second process of calcination. This double-kilning would, where fuel was relatively cheap, entail but little more cost and perhaps less labor than first grinding the limestone to fine powder under millstones and then mixing it with the clay, as is now done in the dry process of manufacturing Portland. Moreover, by the slaking action, the lime is obtained in an extremely fine state of subdivision, and therefore in a condition peculiarly well adapted for intimate admixture with the clay.

Aspdin fails to point out the exact amount of clay needed, rather an important matter in a specification, one would think, and he omits to state that the firing must be carried on until incipient vitrification is attained.*

The growth of the artificial or Portland cement industry was for many years very slow. In 1848 the son of the inventor formed a company and began the manufacture of the cement at Rotherhithe, near London. In a circular issued by this company it claims "that in consequence of improvements introduced in the manufacture, it will be found, for the following reasons, infinitely superior to any cement that has hitherto been offered to the public:

"(1) Its color so closely resembles that of the stone from which it derives its name as scarcely to be distinguishable from it.

"(2) It requires neither painting nor coloring, is not subject to atmospheric influences, and will not, like other cements, vegetate, oxidate, or turn green, but will retain its original color of Portland stone in all seasons and in all climates.

"(3) It is stronger in its cementative qualities, harder, more durable, and will take more sand than any other cement now used."

At the great exposition at Hyde Park in 1851, Portland cement was first brought prominently before the public, and tests were made showing its superior tensile strength, a crude form of the briquette now in such common use for testing, being, for the first time, used. Soon after this public exhibition of its qualities, its manufacture was begun on the Continent, where it gradually grew into enormous proportions, especially in Germany, that country for many years not only making its own supply, but exporting to the United States nearly two-thirds of the amount there used. Its manufacture also increased greatly in England where, at the present, it is made chiefly in the Thames and Medway districts, where white and gray chalk and river mud are used. In France the materials employed are marls, chalks, and clays. In Germany the more important centers of production are in the northern portion, especially the regions

* Redgrave—"Calcareous Cements," 1895, p. 25.

about Stettin and the Rhine Valley. Here, also, chalks and marls form the principal sources of the lime.

PORTLAND CEMENT INDUSTRY IN THE UNITED STATES.—Portland cement was first manufactured in this country in 1872, near Copley, Lehigh County, Pennsylvania, at a locality in which natural rock cement had, up to that time, been made. A second factory was soon after established at Wampum, Lawrence County, Pennsylvania, where the materials used were fossil limestone and clay.

On account of a lack of knowledge of the more technical processes of manufacture, as well as on account of the prestige which the foreign-made cement had secured among contractors and engineers, the growth of the Portland cement industry in the United States was very slow up to 1890. In that year the total output of the eighteen factories then in operation in this country was only 335,500 barrels, valued at $704,050. From 1890 to 1900 the growth of the industry in the United States was exceedingly rapid, and during the last half of this period almost phenomenal. The amount consumed in 1899 was very nearly three times that in 1890, while the imports have been reduced but slightly below what they were in 1891. The following table shows more graphically than words the increase by years in production and total consumption, as well as the variation in the amount imported:

COMPARISON OF THE DOMESTIC PRODUCTION OF PORTLAND CEMENT WITH THE IMPORTS.

(Barrels.)

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
Production in the United States	335,500	454,813	547,440	590,652	798,757	990,324	1,543,023	2,677,775	3,692,284	5,652,266
Imports	1,940,186	2,988,313	2,440,654	2,674,149	2,638,107	2,997,395	2,989,597	2,090,924	2,013,818	2,108,388
Total	2,275,686	3,443,126	2,988,094	3,264,801	3,436,864	3,987,719	4,532,620	4,768,699	5,706,102	7,760,654
Exports	....	....	21,536	14,276	9,725	83,682	85,486	53,466	36,732	110,272
Total consumption	....	3,443,126	2,966,558	3,250,525	3,427,139	3,904,037	4,447,134	4,715,233	5,669,370	7,650,382
Percentage of total consumption produced in the United States	....	13.2	18.4	18.2	23.3	25.4	34.7	56.8	65.1	73.9

From the table it will be seen that in 1897, the total increase in domestic production was 1,134,652 barrels, while the increase in consumption was 368,099 barrels. This was the first year that the increase in production was greater than that in consumption, and also the first year in which American manufacturers produced more than one-half of the Portland cement consumed in the United States.

According to Mr. S. B. Newberry, the acknowledged authority on Portland cement in this country, "This important step toward the replacement of imported by domestic Portland was largely brought about by the successful efforts of American manufacturers to produce a high grade product. Engineers in all parts of the country found to their surprise that the product of the leading American factories showed decidedly higher tests than the imported brands which had long been regarded as a standard. In fineness of grinding, also, the American cements were found superior to the imported. Nevertheless the fact remains that there is among contractors a considerable prejudice in favor of certain brands of German cements, and that the latter still command a higher price than the American. This prejudice is unfounded, and is therefore certain to depart in time, but it still exists. American cements can be made at a price which will allow them to be sold cheaper than the best imported German, and where the two come together in competition on large contracts the work is generally made to the American manufacturers on the basis of price. This was clearly shown on the letting of a large government contract at Pittsburg last winter. The offers were as follows:

One Belgium cement	$2 50 a bbl.
Five German cements, average price	2 60 a bbl.
Four American cements, average price	2 28 a bbl.

"The price of Portland cement is steadily coming down and the fall is being hastened greatly by the successful competition of American against foreign manufacturers. There can be no doubt that within a very few years practically all the Portland cement consumed in this country will be of domestic manufacture. The prices of some, however, will hardly be the same as they are now. When the demand is completely supplied by American manufacturers we shall have works in this country producing 2,000 barrels a day more than in Germany and the same result will be reached here as in Germany, namely, the complete replacement of the common natural rock cements by artificial Portland."*

* Brickbuilder, 1898, p. 108.

The following table shows the production of Portland cement by States in 1898 and 1899:

*PRODUCTION OF PORTLAND CEMENT IN THE UNIIED STATES IN 1898-1899.

STATE.	1898.			1899.		
	Number of Works.	Product. (Barrels.)	Value, Not Including Packages.	Number of Works.	Product. (Barrels.)	Value, Not Including Packages.
Arkansas	......	....	....	1	50,000	$87,500
California	1	50,000	$100,000	1	60,000	120,000
Illinois	......	....	....	2	53,000	79,500
Indiana	1	2,500	4,375	......	....	....
Maryland	1	10,000	17,500	......	....	....
Michigan	2	77,000	134,750	4	342,566	513,849
New Jersey	2	587,163	1,027,535	2	892,167	1,338,250
New Mexico	......	....	....	1	1,500	4,500
New York	7	554,358	970,126	7	472,386	708,579
North Dakota	......	....	....	1	1,700	5,100
Ohio	6	265,872	465,276	6	480,982	721,473
Pennsylvania	8	2,095,141	3,142,711	9	3,217,965	4,290,620
South Dakota	1	31,000	62,000	1	35,000	70,000
Texas	1	8,000	24,000	......	....	....
Utah	1	11,250	22,500	1	45,000	135,000
Total	31	3,692,284	$5,970,773	36	5,652,266	$8,074,371

* From the article on Portland cement by S. B. Newberry, in the Twenty-first Annual Report of the U. S. Geol. Surv.

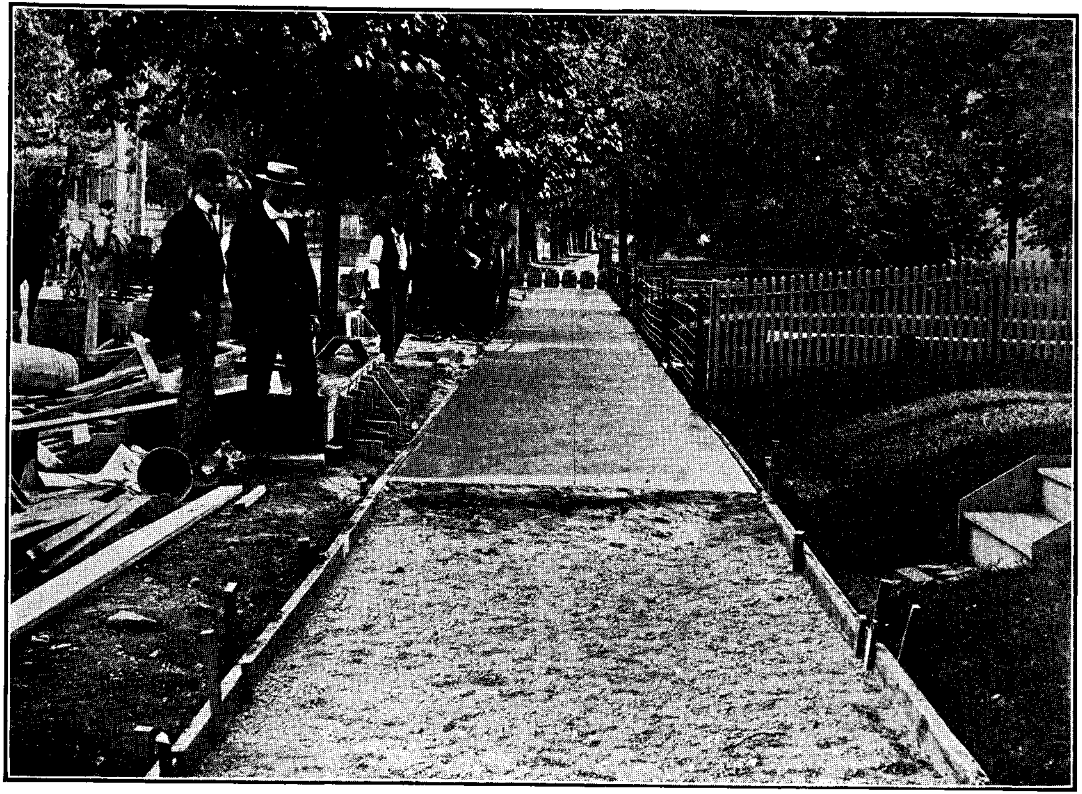
From this table it will be seen that the increase in production in 1899 was 1,959,982 barrels, or 53.1 per cent. This is the greatest increase in number of barrels of any year in the history of the industry in the United States, though the percentage of increase was greater in both 1896 and 1897, when it was respectively 55.8 and 73.5 per cent. That the domestic production has not been lessened by any decrease in the demand is shown by the table on page 5, where it will be seen that the imports since 1891 have been more than 2,000,000 barrels each year, while the imports for 1899 were 94,570 barrels in excess of those for 1898. In both 1898 and 1899 the demand in the autumn months was far in excess of the supply, and many important engineering works were suspended or delayed on account of the impossibility of securing the cement. A number of factories had their output sold almost a year in advance, and high prices were paid in many instances for immediate shipment. The same condition existed in other countries, and as a result many new companies were organized and factories erected, both here and abroad, for the production of cement.

From the table it will also be seen that in 1899 the average price per barrel of 380 pounds, exclusive of cost of barrel, was $1.43. No data are available for securing the average price for 1900, but to the actual consumer, the price, even in large lots, was much higher. On the 10th of August, 1900, the Indianapolis Waterworks Company paid $2.37 per barrel in jute on board cars at Indianapolis for 4,000 barrels from an Ohio factory. On the other hand, a county surveyor was able to purchase, about the same date, a 700 barrel lot for $2.19 per barrel. The Whitehall Portland Cement Co., of Cementine, Pa., make a cement by the dry process from ground limestone and clay at a cost of 55 cents per barrel. Their plant is a very large one, costing over $700,000, and is fitted with the latest and most improved machinery. A careful estimate shows that the cost of making the cement, by the wet process, from marl and clay, including all general expenses, is, in such States as Michigan, Ohio and Indiana, about 66 cents per barrel; so that the margin of profit is still sufficiently high.

USES.—One of the principal reasons for the great increase in consumption of Portland cement in this country in recent years is the discovery of many new uses for which it is especially fitted. Its list of possible uses has, in fact, more than doubled in the past five years. Soft and readily molded or shaped into any desired form when fresh; but if properly used, soon becoming harder and more durable than stone, impervious to moisture or vermin and perfectly fire proof, it is rapidly replacing not only stone, but also wood and iron for many purposes. In all great engineering enterprises it is being used to a far greater extent than ever before. Up to the present, and no doubt for many years to come, the demand has been and will be limited by the supply. As fast as new factories are established the market swallows up their product, and, up to the present, without effort or appreciable effect upon the price.

On account of its fireproof qualities and its imperviousness to moisture and vermin, Portland cement is especially suitable for the construction of all absolutely fireproof buildings, especially art galleries, museums, etc. The museum at Stanford University, California, now being erected, is a notable example of its kind. It will

PLATE 2.



ILLUSTRATING USES OF PORTLAND CEMENT.

Sidewalk of Portland Cement Concrete in Process of Construction on Meridian Street, Indianapolis, Ind.

be 300 feet in length, three stories in height, and the entire structure from foundation up—floors, walls and roof—will be of concrete and iron. The whole edifice is to be molded into a single monolithic structure without seam, joint or break. The bars of iron are embedded in the concrete and are immovably held at every point by the enveloping material, thus imparting their own tensile strength to the concrete, which obviates the necessity for great thickness or heavy weight. If the materials be mixed by machinery, the walls of a building can be built of concrete for 22 cents a cubic foot, more than 10 cents less than common brick work. For columns, cornices, doors, windows, and all moldings and ornaments its relative expense is at least from one-third to one-half less than that of cut stone as, after the moulds are made, the whole work can be done by unskilled labor. For any large public building designed to be fireproof, it is, therefore, the most economic material available.

Its use by railways for the construction of bridge piers, arch culverts, abutments, retaining walls, etc., is just beginning, and bids fair to assume enormous proportions. "Concrete culverts and bridge piers are particularly well adapted for use in the construction of new lines of railway, owing to the comparative ease with which the material for making concrete can be transported, as against heavy stone work. The use of derricks for loading and unloading material and specially constructed wagons for heavy hauling are not necessary in concrete work, and as it can be made with cheap, unskilled labor, a great saving in the wages of the force employed is thus effected. These culverts have a decided advantage over cast-iron pipes on new works owing to the great cost of transporting pipe."*

Especially will this increase in the use of Portland cement concrete become notable in the great Central Valley and Prairie States, where timber is becoming scarce or is wholly absent and where suitable stone has often to be transported for hundreds of miles. The increasing use of such concrete in these regions is but a natural economic development.

For breakwaters, large sewers, dams, piers, and other structures on and about the sea coast, great lakes, and larger streams of the country, concrete has no equal, either in durability or ease of transportation and construction. For railways and for national, state and municipal public works its growing consumption will be sufficient to utilize for many years, all the output of the many new factories which are proposed. Hence, while the growth of the Portland cement industry at this time is very rapid, there need be little fear

*F. G. Jonah in Canadian Engineer.

of an overproduction or of a failure to find an adequate market for the product.

The following is a partial list of the many uses to which Portland cement, or concrete made largely from this cement, is now being put:

USES OF PORTLAND CEMENT.

Abutments.
Arched culverts.
Artistic tile for inside decoration.
Artificial stone columns.
Asphalt pavements.
Bank vaults.
Cellar bottoms.
Chimneys, especially the tall ones of factories and mills.
Concrete sidewalks.
Curbs and gutters.
Dams and wheel pits in water powers.
Dry docks.
Engine beds.
Fence posts.
Fireproof floors.
Fortifications.
Foundations and walls for all fireproof buildings.
Foundations for brick and other street pavements.
Grain elevators.*
Irrigation flumes.
Lining of war vessels.
Locks of canals.
Mill races and water courses in general.
Monolithic concrete construction in general.
Pier, quay and breakwater construction.
Piling.
Pipe mains.
Railway ties.†
Reservoirs for water supply of cities, for sewage, etc.
Retaining walls for wharfs and embankments.
Sewers.

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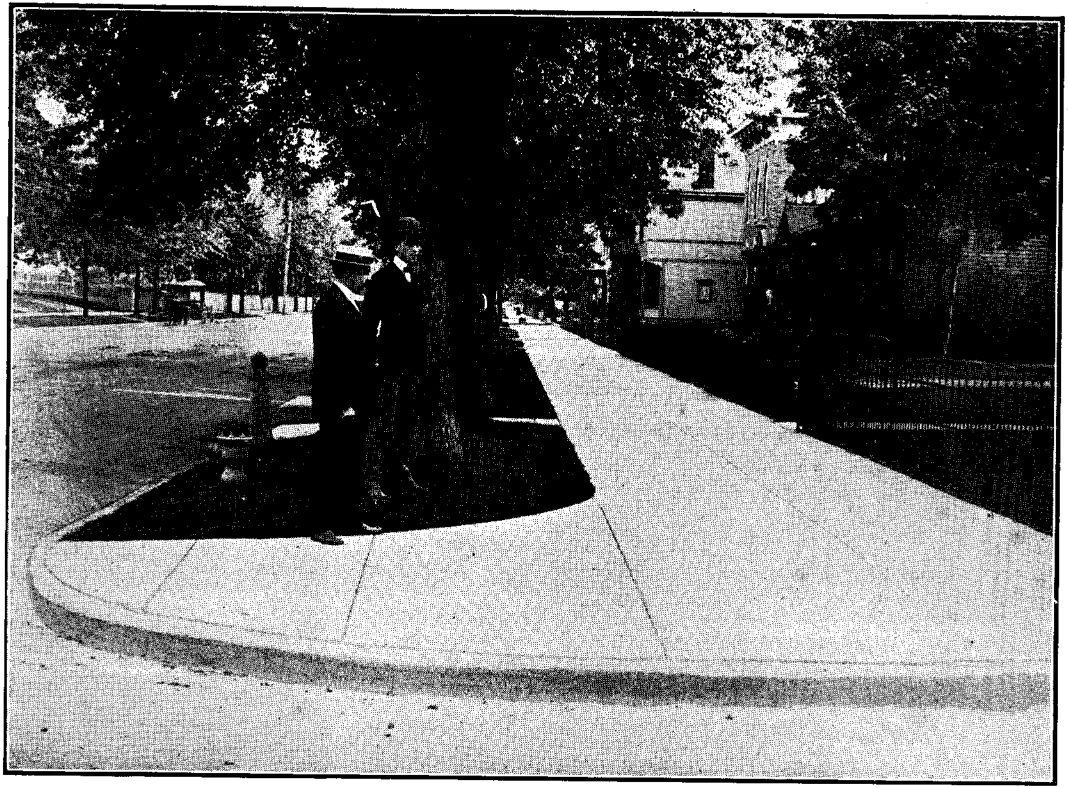
*The Interior Elevator Co., of Minneapolis, Minn., will soon erect a large grain elevator for Duluth, to be constructed entirely of steel and Portland cement concrete, such as is in use on the Danube in Europe. The estimated cost for this elevator is nearly $1,000,000.

†Concrete railway ties are coming into use in Europe and oriental countries; and it will be but a few years until they will be extensively used in the United States.

PLATE 3.



ILLUSTRATING USES OF PORTLAND CEMENT.

Sidewalk of Portland Cement Concrete Completed, on Meridian Street, Indianapolis, Ind.

Shingles and tiles for roofs.*

Stairways in public and private buildings.

Stuccoing for the exterior of old brick and frame buildings.

Terra-cotta blocks.†

Tunnel linings.

Vaults and burial tombs.

Germany, with a population of 50,000,000, manufactures about 18,000,000 barrels of Portland cement each year. Its exports are a little over 3,000,000 barrels, leaving 15,000,000 barrels for home consumption. The United States, with a population of 75,000,000, consumes about 7,650,000 barrels per year. The consumption per capita is therefore three times greater in Germany than in the United States. On account of the far greater magnitude of the engineering and railway operations in the United States there is little doubt but that the consumption of Portland cement will increase until it exceeds, per capita, that of Germany.

Composition.—The essential ingredients or elements entering into Portland cement are calcium, silica and aluminum. The calcium is furnished either by a limestone or marl; the silica and aluminum by clay. In the process of burning, these three elements unite to form a complex silicate. It is therefore necessary that they be combined in the proper proportions if the best results are to be obtained. In a few places in the United States, notably the Lehigh Valley region, Pennsylvania, natural deposits of stone occur in which the elements of Portland cement are found already existing in the proper proportions. It is in this region, comprised within a circle of fifteen miles radius, that the greatest development of the industry in the United States is found. There are at present in this region eleven factories, two of which are larger than any others in the world. One of these is producing over 8,000 barrels per day, while 4,110,132 barrels, or nearly four-fifths of the entire product of the United States, was produced by the eleven factories in 1899. In the rock of the Lehigh Valley region there is a slight excess of clay; a small proportion of pure limestone is therefore ground with the rock to produce a correct mixture.

In other places a pure limestone and clay are ground together for the cement. In this case the grinding of the stone must be much finer than where the natural Portland cement stone is used, since any coarse particles of the latter which may remain in the raw

* In Germany 40 per cent. of the burnt clay roofing tile has been replaced by concrete tile during the past 10 years.

† These blocks, made of concrete and molded in imitation of terra cotta, are being extensively used for external walls of dwellings and business houses.

material are of nearly correct composition. The use of marl as the form of carbonate of lime has greatly increased in the past few years, the new factories which have been erected in Michigan, Ohio and Indiana generally using that material. The following table gives the comparative product of Portland cement from limestone and marl for the years 1897, 1898 and 1899:

	1897.		1898.		1899.	
	Number.	Product.	Number.	Product.	Number.	Product.
		Barrels.		*Barrels.*		*Barrels.*
Factories using limestone.........	18	2,282,126	20	3,112,492	24	4,697,722
Factories using marl	11	395,649	11	579,792	12	954,544
Total.........................	29	2,677,775	31	3,692,284	36	5,652,266

The chemistry of Portland cements has been very carefully studied by Messrs. S. B. and W. B. Newberry who, from a long series of experiments, have deduced the following conclusions:*

"First. Lime may be combined with *silica* in the proportion of three molecules to one, and still give a product of practically constant volume and good hardening properties, though hardening very slowly. With three and one-half molecules of lime to one of silica the product is not sound, and cracks in water.

"Second. Lime may be combined with *alumina* in the proportion of two molecules to one, giving a product which sets quickly, but shows constant volume and good hardening properties. With two and one-half molecules of lime to one of alumina the product is not sound.

"Assuming that the tri-silicate and di-aluminate compounds above mentioned are the most basic compounds which can exist in good cements, we arrive at the following general formula for cements:

$$(X\,(3CaO.SiO_2) + Y\,(2CaO.Al_2O_3),$$

in which X and Y are variable quantities, having different values according to the relative proportions of silica and alumina present in the clay employed.

"The formula $3CaO.SiO_2$ corresponds to 2.8 parts of lime, by weight, to one part of silica.

"The formula $2CaO.Al_2O_3$ corresponds to 1.1 parts of lime, by weight, to one part of alumina.

*"The Constitution of Hydraulic Cements," 1897, p. 7.

"Substituting weights for equivalents, we have the following formula, representing the maximum of lime which should be present in a correctly balanced cement:

"The per cent. of lime = the per cent. of silica × 2.8 + the per cent. of alumina × 1.1.

"This formula may be used to calculate the proportion of lime which should be used with any clay of known composition as follows: *Multiply the percentage of silica by 2.8, and the percentage of alumina by 1.1; add the products; the sum will be the number of parts of lime required for 100 parts clay.*

"As 2.8 parts lime correspond to 5.0 parts carbonate of lime, and 1.1 parts lime correspond to 2.0 parts carbonate of lime, the calculation may take the following simple form: *five times the percentage of silica, plus twice the percentage of alumina, = the number of parts of carbonate of lime required for 100 parts of clay.*

As a practical example of the use of this formula, let us suppose a clay of the following composition:

Silica	65.4
Alumina	16.5
Iron oxide	6.1
Lime	2.2
Magnesia	1.9
Moisture, combined water, etc.	7.9
Total	100.0

"Let us now calculate the amount of lime (or carbonate of lime) which must be added to this clay to produce a correct cement mixture:

% Silica = 65.4 × 2.8 =	183.12 lime.
% Alumina = 16.5 × 1.1 =	18.15 lime.
Total	201.27
Less lime contained in clay,	2.20
	199.07

Therefore 199.07 parts of lime are required for 100 parts of clay.

"As 56 parts of lime correspond to 100 of carbonate of lime, we have

$$\frac{199.07}{56} \times 100 = 355.5.$$

Therefore 355.5 parts of carbonate of lime are required for 100 parts of clay.

"The correct mixture would then be:

100 parts clay.
355.5 parts pure carbonate of lime.

"The percentage of carbonate of lime in this mixture would be 78.0. On burning this a cement of high quality will result, provided the materials are finely ground and perfectly mixed. This statement was confirmed by practical test; an excellent cement of constant volume resulted.

It will of course be understood that the proposed formula represents the *maximum* of lime which can be used with safety. This maximum can be reached in practice only by most thorough grinding and mixing of the raw materials. In practice the preparation of the materials is always imperfect, and a certain part of the silica and alumina present remains inactive, as is shown by the occurrence of a small percentage of insoluble matter in all commercial cements. For this reason the proportion of carbonate of lime is usually carried about one to two per cent. lower than that called for by the above formula."

According to Dr. Michaelis, the ratio of the total silicates to the lime should be about as 1 to 2, and the variation from this ratio should only be within narrow limits. Cements rich in lime set more slowly, but harden to a greater degree than those poor in lime. Cements rich in silica generally set more slowly than those rich in alumina, but the former harden very quickly and are better for use in contact with ocean water. The celebrated German Portland cement manufactured at Stettin has a silica percentage of nearly 25 per cent. with 5.7 per cent. of alumina and 2.5 per cent. of ferric oxide.

From a series of experiments the Messrs. Newberry concluded that:

"Iron oxide (Fe_2O_3) combines with lime at a high heat, and acts like alumina in promoting the combination of silica and lime. For practical purposes, however, the presence of iron oxide in a clay need not be considered in calculating the proportion of lime required," and that "alkalies, so far as indicated by the behavior of soda, are of no value in promoting the combination of lime and silica, and probably play no part in the formation of cement."*

In regard to the alkalies, the German chemist, Schoch, expresses the opposite opinion from the Newberrys, and considers that these alkalies act as a flux and are of great benefit in connection with the

*Loc. cit., p. 16.

hardening process of cement, as they convert the silica into a soluble condition so that it combines readily with the lime when wet. Since these alkalies act so powerfully in bringing about the vitrification of clays in the burning of such products as sewer pipe and paving brick, there can be but little doubt that they have a somewhat similar effect, or at least lend much aid to the proper calcination or vitrification of the slurry or cement material during its progress through the kilns.

The question of the influence of magnesia as one of the ingredients of Portland cement has been studied by many chemists, but is, as yet, unsettled. It is held by several prominent authorities that the presence of any considerable amount of magnesia causes the cement to expand and crack after a time. R. Dykerhoff, a German authority, claims that more than four per cent. of magnesia, either added to a normal mixture or substituted for an equivalent percentage of lime, causes a steady deterioration in the strength of the resulting cement. Actual cracking was observed only when 8 per cent. or more of magnesia was present. The Messrs. Newberry, by a series of tests, found that pure magnesia, when calcined at a high temperature, sets with water and hardens like cement but is not constant in volume. Compounds of magnesia with alumina and silica did not set or harden in air, water or steam. When calcined with clay, the magnesia decomposes the clay, but the action is far less complete than in the case of lime; and the product of calcination had no setting or hardening properties. Magnesia is not capable of replacing lime in cement mixtures, the composition of which should be calculated on the basis of the lime only. On the whole it is believed that two and a half per cent. of magnesia is the maximum amount which a good grade of Portland cement can contain, though some German products contain as high as three and a half per cent.

Sulphur is another element which is harmful to cement, especially when the latter is exposed to sea water, as its presence in any quantity hastens disintegration. The source of the sulphur may be either calcium sulphate in the marl or clay, or iron sulphide in the coal used as fuel. An addition of one-third to three-fourths per cent. of fluorspar is often very beneficial for bringing about an easy clinkering of the material in the kiln.

The clay used in the making of Portland cement should not contain an excess of sand or free silica. Many clays contain a high percentage of sandy particles not in combination with the other elements. Such clays possess a harsh, gritty feeling when rubbed between the finger and thumb or when brought in contact with the tongue and it is possible to wash out from them a considerable quantity of grains of sand. These clays, though well adapted for brick making, are not suitable for cement.

The clays best adapted for Portland cement are fine grained and have a greasy or unctuous touch; any free sand present must be removed or ground fine. The amount of silica in the clay used in the best grades of cement runs from 58 to 65 per cent. The more amorphous silica present, the better the clay. The amount of iron oxide present should not exceed 10 per cent. Clays low in iron are usually of a gray or blue color and change to light yellow when weathered.

The following are the analyses of some of the clays used in the making of European and American Portland cements:

	1	2	3	4	5	6	7	8	9	10
Silica (SiO_2)	60.06	59.25	60.00	62.48	64.72	64.70	62.10	69.49	56.54	57.98
Alumina (Al_2O_3)	17.79	23.12	22 22	20.00	24.27	11.90	20.09	} 16.42	19.43	18.26
Ferric Oxide (Fe_2O_3)	7.08	8.53	8.99	7.33	7.64	9.90	7.81	}	4.83	4.57
Lime (Ca O)	9.92	......	4 18	6.30	1.89	.9	.65	2.29	7.27	1.75
Magnesia (MgO)	1.89	2.80	1.60	1.16	......	.7	.96	.78	3.05	1.83
Potash (K_2O)	2.50	1.87	1.49	1.74	1.90	......	......	....	......	......
Soda (Na_2O)	.73	1.60	.72	.37	2.10	......	......	....	......	......
Calcium sulphate ($CaSO_4$)	.60	2.73	.89	.60	......	......	.49	....	......	1.28

The above clays are used in making cement at the following localities:

Europe.

1. Province of Saxony.
2. Vorpommern.
3. Oberharz.
4. Brandenburg.
5. Medway.

America.

6. Sandusky, Ohio.
7. Bronson, Michigan.
8. Wellston, Ohio.
9. Stroh, Indiana.
10. Yankton, South Dakota.

It will be noted that the percentage of alumina in the above clays ranges between 11.90 and 24.27 per cent. Cements low in lime and without an excess of alumina but high in silica are always of low tensile strength. If the alumina in the cement runs above 8 per cent. it is considered high, if below 5 per cent., it is very low. Since the clay is the source of all the alumina, and almost all of the silica, too great an amount of clay will cause the resulting cement to fuse too easily. It will also be light in weight, will set quickly, have a brownish color and never become thoroughly hard. Moreover, it will crumble to a greater or less degree when exposed to the weather. On the other hand cements containing too great a percentage of lime will stand the hottest fire without fusing. When burned, such cements are slow setting, hard to grind, and liable to flow and swell after being used. In most of the Portland cements now on the market the lime runs from 60 to 65 per cent.

The following is a table of chemical analyses of some of the leading makes of European and American Portland cements:

	Dykerhoff. (German)	Germania. (German)	Ports. (German)	Empire. (American)	Saylor's. (American)	Sandusky, O. (American)	Bronson. (American)	Diamond. (American)
Lime (CaO)	63.06	63.72	62.28	60.92	62.30	64.19	63.17	61.90
Silica (SiO_2)	20.64	22.08	22.69	22.04	22.68	23.20	20.95	21.80
Alumina (Al_2O_3)	7.15	6.84	7.30	6.45	6.71	7.03	9.74	7.95
Iron Oxide (Fe_2O_3)	3.69	3.36	2.87	3.41	2.35	2.41	3.12	4.95
Magnesia (MgO)	2.33	1.32	1.08	3.53	3.14	.97	.75	1.64
Sulphuric Acid (SO_3)	1.39	1.82	1.62	2.73	1.88	1.05	.86	.79

The table shows that the composition of the Portland cements now on the market is very uniform, the limit of variation of each constituent in the analyses given above being less than three per cent.

Process of Manufacture.—In the making of Portland cement from marl and clay, the process now followed in most of the factories in Ohio, Michigan and Indiana is what is known as the "wet process," the materials, after being carefully proportioned and thoroughly mixed being introduced into the kilns in a moist or semi-moist condition. "To accurately proportion the raw materials and to perfect an intimate mixture of them are the prime factors in making good Portland cement. Other things being equal the more exactly the proportions are maintained the greater the uniformity of the cement; the more homogeneous the mixture and the finer the state of division of its particles, the greater the strength and hydraulic energy of the product."*

In some plants the mixing is begun in large steel wet pans having a diameter of eight to ten feet, water being allowed to flow onto the ingredients while they are being ground. From the wet pans the mixture is pumped or forced through steel pipes into ball mills where the particles of clay and marl are brought into still more intimate connection. From the ball mill the mixture or "slurry," as it is now called, is passed into revolving steel kilns.

In other plants the clay is first passed through horizontal cylindrical steel dryers, where it is brought into direct contact with hot air, and then through a Williams or other grinding mill, where it is thoroughly pulverized. From these mills it passes into steel storage bins, and from there, as needed, into pug mills, which correspond to

*Lewis, Mineral Industry, 1897.

the wet pans above mentioned, where it first comes in contact with the wet marl. From the pug mills the mixture goes to the ball mills, which it leaves as slurry ready for the kilns.

The kilns in operation in all of the more modern factories are those of the rotary steel pattern, in which the process of burning is continuous. These kilns were first introduced into the United States in 1889 and crude petroleum was employed for fuel. The oil was blown in by jets at one end and the smoke and gases of combustion passed into a stack at the upper end of the inclined revolving cylinder. As a labor saving device, this kiln had many advantages over the old fashioned, upright intermittent kilns. For a number of years, however, it was handicapped by the varying price of the crude petroleum used as fuel. When this petroleum was only 37 to 48 cents a barrel, as it was between 1891 and 1894, and again in 1897, its use as fuel in cement manufacture was extensive, but when the average price rose above 60 cents, as in 1895 and 1896, and from 1898 on, the cost became prohibitory. Then it was that experiments were made with pulverized coal, and owing to various improvements in its preparation and in the methods of feeding it into the furnace, it is rapidly becoming adopted as a cheap and in every way satisfactory fuel for use in rotary kilns. At the same time the evolution of the mechanical features for handling both the raw materials and burned product in the rotary kiln plants has steadily advanced. As a consequence the amount of manual labor necessary has been materially reduced and the cost of the manufactured product correspondingly lowered. So satisfactory have these results been that in 1899, 20 of the 36 factories in the United States were using the rotary kilns, and in that year 3,711,220 barrels, or 65.7 per cent. of the total production was burned in these kilns, as against 149,000 barrels, or 25.2 per cent. so burned in 1893.

The rotary kilns in use vary in size, some being 60x6 feet with a capacity of 160 barrels per 24 hours; others 60x5 feet, with a capacity of 125 barrels. They are so set that the back end is a foot or two higher than the lower or front end. The coal used is bituminous and usually a mixture of slack and nut. In some factories it is dried in upright steel dryers encased in brick, the hot air being applied between the brick and the steel, and then ground in revolving tube mills; in other factories it is dried in rotary cylinders about 4x50 feet in size, and afterward ground in Griffin or similar mills. After grinding it is conveyed to storage tanks. In the latest and most improved plants, these are flat funnel-form, made of heavy sheet iron, one being fastened to the walls about six feet above the ground, and in front of each rotary kiln. The coal, when prepared as described, is in the form of a fine powder, and is forced by a blower into the front end of the kiln, where it burns like gas, evolving a heat of 3,000 to 3,500 degrees F.

The raw material or slurry mixture enters the kiln by a spout at the upper end and is carried slowly forward and downward by the revolution of the furnace, the burnt clinker finally falling out of an opening at the front end just below the point at which the fuel is forced in. In burning, the furnace is at a white heat 20 to 25 feet back from the front, and at a red heat 10 to 15 feet back. The material, in passing through, is kept at a high heat only 15 to 20 minutes, although it is in the kiln about three times as long. It emerges in clinkers the size of a hickory-nut or less. These are lifted by endless bucket elevators and are then stored in steel cooling bins, or are passed through troughs of water and so cooled immediately. In some factories it is customary to add about two per cent. by weight of raw ground gypsum to the cooled clinker to prevent the cement from setting too quickly.

From the cooling bins or troughs the clinkers go to the final grinding machines. These are either of the Griffin or the ball and tube pattern, and from them the cement emerges as a finished product. From these mills it is conveyed to the storage bins where it is usually kept 60 days or more before being shipped for consumption. This seasoning increases the tensile strength by neutralizing the free lime remaining in the cement.

From what has been written it will be seen that the manufacture of Portland cement is an operation requiring great care and skill. The selection, preparation and mixing of the raw materials, the burning of the charge, and the sorting and grinding of the product, must all be carefully controlled, or serious defects in the finished product will result. The faults shown by bad cements are, moreover, generally not trifling ones, nor immediately evident, but often consist of hidden and dormant evils, which may cause the failure and destruction of important pieces of engineering work after the lapse of months or years. It is evident, therefore, that simple and rapid methods of detecting these hidden faults, and of determining the comparative values of different samples of cement, are absolutely indispensible to all engaged in the many kinds of constructive work in which cement is used.

THE TESTING OF PORTLAND CEMENT.—Each of the leading factories now has, as an adjunct to its plant, a laboratory in which an experienced chemist is constantly at work, making analyses of the raw materials and the completed product, and also carrying on numerous tests to show the setting and hardening properties, the tensile and compressive strength, and the permanence in water and air of the cement manufactured. Each of the great engineering departments of the different nations, as well as those of different cities, have certain special requirements or specifications which each brand of Portland cement offered must satisfactorily meet before it will be accepted for use. The requirements vary much, and are based not only upon the special use to which the cement is to be put, but also, oftentimes, upon the whim or judgment of the engineer in charge. Some engineers require only a proper tensile strength to be shown. Others require satisfactory proof of many qualities other than those above mentioned. The following are the

SPECIFICATIONS OF THE ENGINEERING DEPARTMENT, DISTRICT OF COLUMBIA.

Fineness.—Not less than 95 per cent. to pass a 50 mesh sieve, and not less than 85 per cent. to pass a 100 mesh sieve.

Time of Setting.—Initial set in not less than one hour.

Tensile Strength.—One day, neat, 125 lb.; 7 days, neat, 400 lb.; with three parts sand, 100 lb.; 28 days, neat, 500 lb.; with three parts sand, 150 lb.

Constancy of Volume.—Portland cement shall not contain more than 3 per cent. of free lime, and shall withstand without cracking a temperature of 212 degrees F. after immersion in water for 24 hours.

The city of Philadelphia in 1898, required only a test for tensile strength as follows:

Neat—24 hours, 180 pounds.
7 days, 500 pounds.
28 days, 600 pounds per square inch.
One part cement to three parts sand—
24 hours, 100 pounds.
7 days, 170 pounds.
28 days, 240 pounds per square inch.

The chief standards of reference among American engineers for the testing of Portland cement are the recommendations of the American Society of Civil Engineers, drawn up by a committee appointed to devise a uniform system of testing. The report of this committee, published in the proceedings of the society for June, 1885, contain, among others, the following important recommendations:

"Fineness.—Cement of the better grades is now usually ground so fine that only from 5 to 10 per cent. is rejected by a sieve of 2,500 meshes per square inch (50 mesh). The finer the cement, if otherwise good, the larger dose of sand it will take, and the greater its value.

"Checking or Cracking.—Make two cakes of cement, two to three inches in diameter, one-half inch thick, mixed with water to the consistency of stiff plastic mortar. Note the time required to set hard enough to stand the wire test recommended by General Gilmore, 1/12 inch diameter loaded with ¼ pound, and 1/24 inch diameter loaded with 1 pound. One of these cakes, when hard enough, is placed in water and examined from day to day to see if it becomes contorted or cracked. The remaining cake should be kept in air and its color observed.

"Tensile Strength.—The cement is to be tested neat and also with three parts sand. The amount of water required is approximately as follows: Neat Portland cement, 25 per cent.; cement with one part sand, 15 per cent. of total weight; with three parts sand, 12 per cent. The mixing must be rapid and thorough; the mortar, which should be stiff and plastic, should be firmly pressed into the molds with the trowel, without ramming, and struck off level.

"The temperature of the briquettes and of the testing room should be constant between 60 and 70 degrees F.

"The sand recommended is the *crushed quartz* used in the manufacture of sandpaper, of such fineness as to pass a 20-mesh sieve and be caught on one of 30 meshes."

The tests for tensile strength are made with small molded briquettes which are in shape somewhat like the figure 8. The following method of making the cement and sand briquettes is that adopted by the German Minister of Public Works and is probably the best in vogue: For five briquettes weigh out 250 g. (9 oz.) cement and 750 g. (27 oz.) sand. Mix dry, add 100 c. c. water (3½ oz. by weight = 10 per cent.) and work strongly five minutes. The mixture is pressed into the molds so as to fill them above the top, and pounded for at least one minute each with an iron spatula, at first gently from the sides, then more strongly, until the mass becomes elastic and water appears on the surface. The spatula should be 14 inches long, the blade 1⅛ by 2 inches, and should weigh about 250 g. (9 oz.). Briquettes are to be kept in a zinc lined box for 24 hours, and then placed in water. Tests are to be made at seven days, 28 days and 12 weeks, and all tests are to be made immediately on taking the test pieces from the water.

The testing machine in most common use is one made by the Fairbanks Scale Co., in which the weight is applied by a stream of shot which runs from a reservoir into a pail suspended at the end of the steel-yard arm; when the briquette breaks the arm falls, automatically cutting off the flow of shot. The actual weight used is multiplied by 100. The time required to break a briquette is about five seconds for every 100 pounds of tensile strength.

Mr. S. B. Newberry has issued a little pamphlet entitled "Notes on Cement Testing" which contains valuable information based upon the results of his experience. In regard to the making of briquettes and the constancy of volume of the cement he makes the following observations:

"The proportion of water used greatly affects the resulting strength. Enough water should be taken to make a stiff, plastic mixture; more than this weakens the briquettes, especially when tested at short periods. Portland cement requires from 22 to 25 per cent. In work so necessarily exact as this, the use of French weights and measures will be found an immense saving of labor and tedious calculation. The cement and sand are weighed in grammes and the water measured in cubic centimeters. Since one cubic centimeter of water weighs one gramme, the correct percentage may at once be taken without calculation.

"The thoroughness of mixing the cement and water makes a most surprising difference. The German requirements specify that the mixture for sand briquettes shall be 'strongly worked with the trowel for five minutes.' The writer found, in one case, that a cement with three parts of sand, worked about one minute, gave at seven days 87 lbs.; the same mixture, thoroughly worked five minutes, gave in seven days 240 lbs. With neat cement thoroughness of mixing is equally necessary. Doubtless many failures and variations in results are due to neglect of this precaution. Rubbing the moist mixture in a large porcelain mortar for a few moments before filling each mold is practiced by some. This method gives higher results, and, if adopted, should be uniformly followed.

"Constancy of Volume.—The tendency of cement to expand or crack is the most dangerous of all the faults it can show, since this may in time cause the destruction of the work in which the cement is used. The pat test on glass is generally relied upon to detect this fault, and should never be omitted. Care should be taken not to put the pats in water until thoroughly set, as the best cements will fail if put in water too soon. For the sake of uniformity it is best to keep the pats for 24 hours under a damp cloth or in a closed box before putting in water. The amount of water used in mixing should not be too great, or the cement will not harden well. The amount specified in the German requirements will be found suitable. The cracks due to expansion occur usually at the edges of the pat, and radiate from the center. These should not be confused with irregular shrinkage cracks, which show themselves when the pats are made too wet and allowed to dry out too much during setting.

"The tendency to expand and crack shows itself much sooner and more distinctly in the pats than in briquettes. Nevertheless the inspection must be continued for a long time, if all possibility of future failure is to be avoided. The writer has known cases in which the pats stood satisfactorily for two weeks or more, but briquettes of the same cement went to pieces after several months. The dangerous expansion of cement is due to free or imperfectly combined lime, resulting generally from coarseness or imperfect mixture of the raw materials. The slaking of this lime is often very long delayed, but finally takes place with irresistible force, completely destroying the hardened cement and the work done with it.

"For the purpose of quickly determining any tendency of cement to expand and crack, the boiling test is largely used. This consists in exposing the pats, after setting, to the action of steam for several hours, then placing them in boiling water for some hours more. The action of steam quickly slakes the free lime, if present, causing the pats to swell, crack and often fall to powder. The writer believes that three hours' exposure to steam is amply sufficient for all practical purposes, and that the boiling water test is unnecessary. A few trials will convince anyone that no cement which cracks in cold water, even after months, can possibly stand the test in steam for three hours. The fact is that no cement is wholly free from uncombined lime, and that a very small percentage of this is entirely harmless. Such a proportion as would be dangerous in practical work is immediately and strikingly detected by the test in steam, and much more surely than by long tests in cold water.

"In using the hot test, care should be taken not to make the pats too wet, since excess of water causes even the best cements to swell up and soften under the action of steam. The writer has found that exposure to steam after setting is a more searching test than that of placing in steam as soon as made. In the latter case, slaking of the free lime appears often to take place before the setting, and the fault thus escapes detection. Pats of sound cement placed in steam after setting will harden rapidly, and show no cracking or crumbling; they will also generally remain attached to the glass, though this point is usually not regarded as essential, since the best cements vary greatly in this respect."

Mr. Newberry also recommends the following as a fair equipment of the apparatus needed for testing cements:

A slab of slate or marble, at least two by three feet in size, one and a half inches thick.

A grocer's scale, weighing to one-fourth ounce.

Set of weights, preferably on the metric system.

A glass graduate for measuring water, preferably showing cubic centimeters.

A trowel with five-inch blade.

Pieces of glass, about five inches square, for pats, and some about three inches square for hot tests.

Testing machine and at least one dozen molds.

A trough for keeping briquettes in water, best lined with zinc.

A square copper box on legs for hot tests, with gas burner, rack for pats, and cover.

THE PORTLAND CEMENT INDUSTRY IN INDIANA.

The first Portland cement factory in Indiana, and one among the first in the United States, was erected at South Bend in 1877, Thomas and Duane Millen, father and son, with John H. Leslie,* being the founders. A factory had, a short time previously, been erected at Kalamazoo, Mich., for the making of Portland cement from marl and clay, but it was not a success. The South Bend factory was, therefore, the first in the United States to successfully use these ingredients in cement making.

The Millens and Leslie began experimenting in June, 1877, and, after making innumerable experiments in proportion and combination of different materials, and building a large number of experimental kilns, they succeeded so far that in the following October they began preparing a small plant to manufacture the cement for the market. They began with one small semi-dome kiln and one millstone with an American cracker to reduce the clinker for the millstone, thus requiring one man with a sledge and a large hollow piece of iron to do the work of a Blake crusher.

They did not succeed in successfully burning any clinker until the latter part of January, 1878, although they were working day and night to find the right proportion for the mixture, the proper

* To Mr. Leslie, still a resident of South Bend, I am indebted for many of the facts here given regarding the early history of the Portland cement industry in Indiana.

way to fill the kiln and the best kind and proper amount of fuel. At last these problems were solved and, with occasional set-backs, they succeeded so well that it was determined to construct another and larger dome kiln. The first year's operation lacked much of being profitable. The second year they constructed a second dome kiln and made many improvements in the methods of mixing, drying and burning, so that at the end of this second year they were nearly even with expense and profit.

The company was soon after reorganized by taking in Homer Millen, a younger son, under the firm name of Millen & Sons, and disposing of their other manufacturing interests, they gave their entire energies to developing their cement plant. The quality of the cement was gradually improved, and the United States Government finally recognized its high grade by annually purchasing large quantities for use in the arsenal at Rock Island, Illinois. The output was, however, small compared with that of factories of to-day, ranging from 5,000 to 20,000 barrels per annum. The cement was made from marl taken from the lakes at Notre Dame and from clay shipped from Bertrand, Michigan, seven miles north.

The analyses of the raw materials, made by H. H. Hooper of Chicago, were as follows:

MARL.

Calcium carbonate ($CaCO_3$)	91.25
Magnesium carbonate ($MgCO_3$)	3.21
Calcium sulphate ($CaSO_4$)	.24
Insoluble inorganic matter (silica, etc.)	3.80
Organic matter	1.50

CLAY.

Silica (SiO_2)	59.36
Alumina (Al_2O_3) and Iron Oxide (Fe_2O_3)	10.01
Magnesia (MgO)	2.40
Lime (CaO)	23.80
Sulphuric acid (SO_3)	1.71
Soda (Na_2O) and Potash (K_2O)	.58
Water (H_2O) combined	2.05

The clay was first ground in a disintegrator, then mixed with the marl in a pug mill in the proportion of one part to four. As it issued from the pug mill it was cut into cakes the shape of an ordinary brick, but larger. These were placed on iron cars and dried 24 to 36 hours by steam and were then burned in an English dome kiln,* four of which, averaging in capacity about 65 barrels of cement each, were in use by the company. These kilns were intermittent in operation. In preparing the kiln for burning, wood and coke were piled for several feet above the grate and then above that the bricks of dried slurry and coke in alternate layers up to the doors at the base of the stack. The doors were then sealed up, the fire started at the bottom and allowed to burn for 64 hours, until it had burned through the clinker at the top. The doors were then opened, and after cooling, the clinkers were removed, the kiln being recharged for another burning. This style of kiln consumes a large amount of fuel and requires more or less sorting of the clinker to separate the underburnt and vitrified material.

At the South Bend factory the clinker, after burning, was run through a Blake crusher and reduced to the size of a hickory-nut or less; then through a "cracker" from which it emerged in pieces the size of a grain of wheat, and then through a rock emery mill for final grinding.

The cement of this factory for many years had a high renown among engineers and contractors. The average tensile strength of its neat briquette was as follows:

24 hours	225 pounds.
7 days	400 pounds.
28 days	550—625 pounds.

while its chemical composition showed the presence of

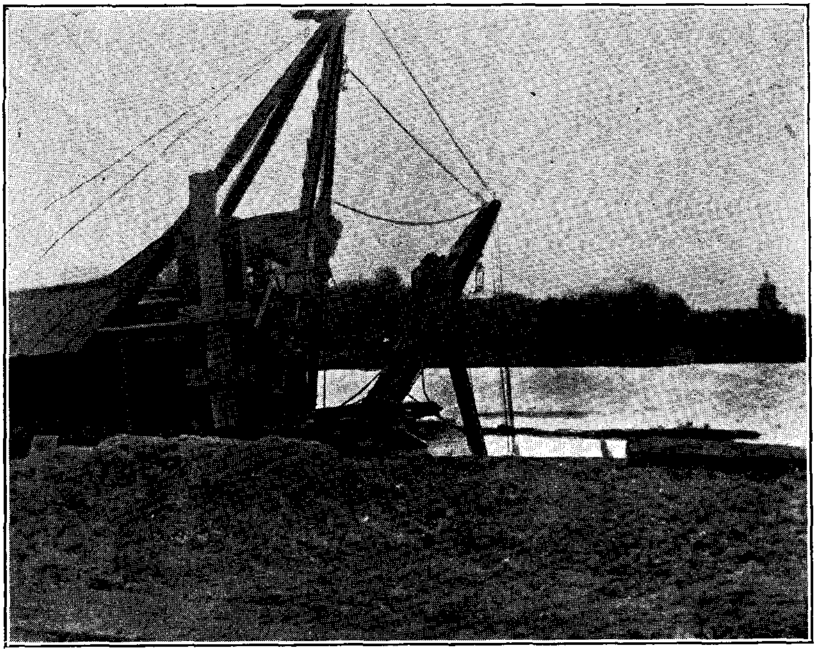
Lime (CaO)	59.24
Silica (SiO_2)	22.30
Alumina (Al_2O_3)	7.21
Iron Oxide (Fe_2O_3)	3.79
Magnesia (MgO)	3.03
Sulphuric acid (So_3)	1.47

In 1886 the original founders, Thomas and Duane Millen, opened up another and larger plant at Warner's, New York, leaving the one at South Bend in the care of Homer Millen and Mr. Leslie. These gentlemen succeeded in increasing the output several hundred barrels per year. The demand for their product continued to increase, so that from 1887 on, the company was constantly refusing orders during the summer and fall months. In 1889, the Millens,

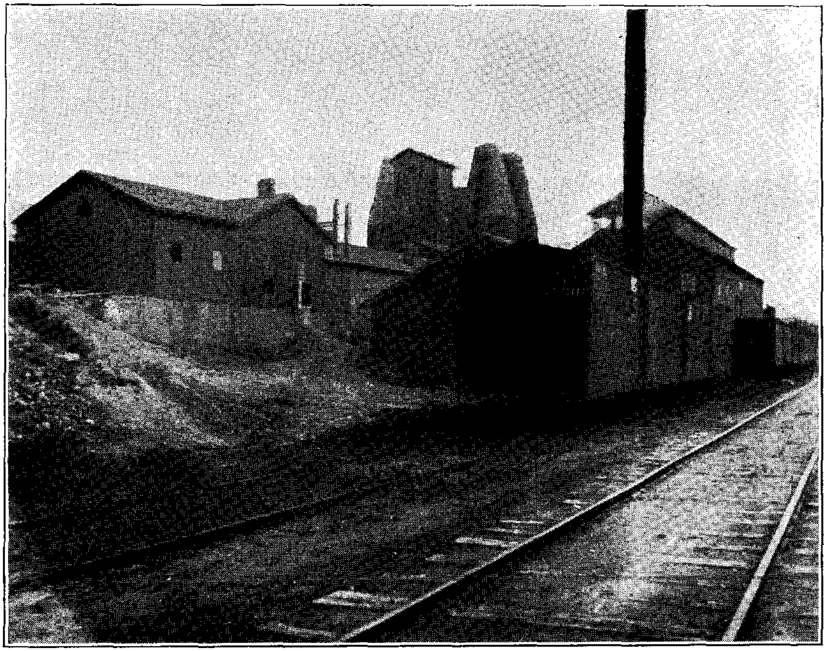
*This style of kiln was the only one used in the United States up to 1889, and next to the rotary continuous, it is the most common one in operation to-day, the process of burning being the same as here described.

PLATE 4.

a



b



THE PORTLAND CEMENT INDUSTRY AT SOUTH BEND, INDIANA.

desiring to concentrate their capital, sold their interests in Indiana to the South Bend Portland Cement Co., consisting of Horace M. Taggart and E. F. Marshall, Mr. Leslie being retained as superintendent. The new company was for two or three years very successful, being several carloads behind their orders during the cement season, although when the season opened they usually had from eight to ten thousand barrels in stock. Tiring at last of declining orders, they concluded to increase their capital stock by reorganizing and building a larger plant. This was begun in the summer of 1891, and late the next spring the new plant was completed at a cost of about $40,000. The machinery consisted of one large Blake crusher; one pug mill; one clay grinder; three sets of millstones; two 80 horse-power boilers; one 125 horse-power engine; three dry arches, fitted with pipes and cars; elevators, conveyers, line-shafting and all other necessary equipments. The burning was done in "dome" kilns of large size, four of which were erected. The plant was in operation only about 18 months, during which time its output was about 60 barrels daily.

Private misunderstandings and dissensions arising among the members of the company, the plant was shut down in 1893, and remained closed until 1896, when it was operated for a short time. Soon after its second opening the company failed, and the plant was permanently closed. It is understood that a Chicago company has recently purchased or leased it, and will use it in making Keene's cement.

The old factory, after having been idle for a year of two, was reopened by a new company in 1894. From a lack of experience the new owners were not able to make cement of as good quality as that produced by the original founders, nor were they able to compete with the lower-priced makes burned in continuous kilns. The output was, therefore, allowed to dwindle, and finally stopped in 1898, the factory having been idle since that year. The high standard attained by the product of the original company shows that the materials used were in every way suited for the manufacture of an excellent grade of Portland cement.

The Wabash Portland Cement Company. — This company began the manufacture of cement at Stroh, Lagrange County, Indiana, in August, 1900. Their plant was erected in 1899 and 1900, on a piece of high ground between Big and Little Turkey lakes, a railway switch having been put in connecting the site with the Chicago Division of the Wabash Railway at Helmer, five miles southeast. With the exception of the chemical laboratory and office, the whole plant is under one roof. It is equipped with the latest improved machinery as follows: One steel revolving dryer, 4x40, and Williams pulverizer for clays; one Vulcan dryer and Smith tube grinder for the reduction of the fuel coal to powder; four rotary continuous kilns, 60x5 feet in size, with a total daily capacity of 480 barrels; 20 steel tram cars, holding one and a half cubic yards each, to convey the marl from the pit to the mouths of the pug mills, three in number; three tube mills for thoroughly mixing the slurry after it leaves the pug mills; and four ball mills for grinding the cement. The capital invested in the plant is at present about $275,-000, though this will soon be increased by the addition of more rotary kilns and other machinery.

According to the statement of the chemist, Mr. W. R. Oglesbey, employed at the works, the average tensile strength of the cement being shipped from the factory in January, 1901, was as follows:*

Neat:	
7 days	**700 pounds.**
28 days	**824 pounds.**
One part cement to three parts sand:	
7 days	**210 pounds.**
28 days	**302 pounds.**

while its average analysis showed the following percentage composition:

Silica (SiO_2)	**21.78**
Alumina (Al_2O_3)	**7.31**
Iron oxide (Fe_2O_3)	**2.65**
Lime (CaO)	**62.35**
Magnesia (MgO)	**2.88**
Sulphuric anhydride (SO_3)	**1.78**
Carbonic anhydride (Co_2)	**.23**
Water (H_2O)	**.55**
Potash (K_2O), Soda (Na_2O) and loss	**.47**

THE SYRACUSE PORTLAND CEMENT COMPANY.—The Syracuse Portland Cement Co. began the erection of a plant by the side of the Baltimore & Ohio Railway, one-third of a mile east of Syracuse, Indiana, in 1899, and completed it ready for the making of cement in November, 1900. The materials used are marl from Syracuse Lake and clay from near La Paz, Indiana.

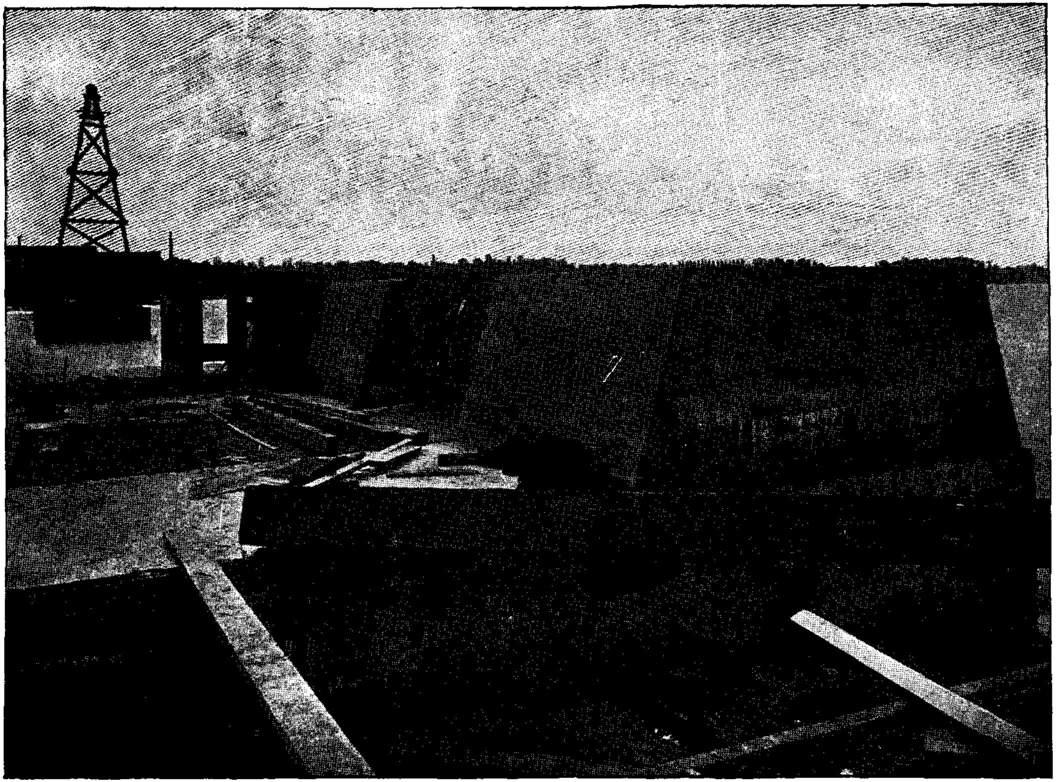
*** An analysis of the clay and marl used will be found under the heading of Turkey Lake, Lagrange County, on a subsequent page of this volume.**

The composition of the marl, clay and cement are as follows, according to S. B. Newberry, chemist:

	Marl.	*Clay (LaPaz).*	*Cement.*
Silica	1.74	55.27	22.06
Alumina	.90	10.20	4.80
Iron Oxide	.28	3.40	1.66
Lime	49.84	9.12	65.44
Magnesia	1.75	5.73	3.82
SO_3	1.12	....	0.90
Loss	46.01	....	....

The different departments of the plant at Syracuse are in separate buildings, thus diminishing greatly the risk of loss by fire. At the same time the arrangements for carrying on the work are so perfected that no waste of labor or increase of machinery is necessitated by this isolation. The buildings erected and machinery installed are in part as follows: (1) Power house, with three sets of boilers; two compound engines of 1,000 horse-power each, and two Westinghouse dynamos each of 440 voltage power. The foundation and floors of this building, as of all the others, is of concrete, the engines being set on concrete foundations reaching to below the level of the water in the nearby lake. (2) Mixing room, 218x62 feet, containing four upright cylindrical storage tanks for marl and clay, each 16x15 feet; two 10-foot wet pans; two steel tube mills, 30x6, for mixing slurry; and three storage tanks 16x15, for slurry after mixture. (3) Rotary building, 100x110 feet, containing six rotary kilns, 60x6 feet, with a total capacity of 960 barrels daily, and six storage tanks, one in front of each kiln, for powdered coal. (4) Coal grinding house, 176x30 feet, containing two steel rotary dryers, each 47x4 feet, and four Griffin mills. (5) Dry grinding house, containing four ball mills and two rotary tube mills. (6) Warehouse, 147x60 feet, with packing room, 45x60, annexed. (7) Store building for supplies and machine shop. (8) Main office and chemical laboratory. The plant is one of the best equipped now in operation in the United States, the amount of capital invested being nearly $400,000. The company is composed mainly of Cleveland and Sandusky, Ohio, capitalists. Preferred stock amounting to $400,000, with a guarantee of 6 per cent. interest, and common stock to the amount of $700,000, was issued. Most of the available marl in and around Turkey or Wawasee Lake has been purchased by this company, and it has also secured, at a cost of $6,000, the only eligible site for a factory by the side of the B. & O. Railway, near Johnson's Bay, Turkey Lake.

PLATE 5.



ILLUSTRATING USES OF PORTLAND CEMENT.

Nearly completed section of Government Breakwater at Cleveland, Ohio, made of Portland Cement Concrete.

Three additional companies have been organized for utilizing some of the Indiana marl deposits, hereinafter described, in the manufacture of Portland cement. These are as follows:

(1) The Indiana Portland Cement Co., with headquarters at Detroit, Michigan, has invested $12,000 in marl and clay lands in and around Dewart and Waubee lakes, Kosciusko County, and propose soon to erect a factory near Milford.

(2) The Goshen Portland Cement Co., at an expenditure of $11,600, secured control of 560 acres of marl land, the former sites of Mud and Cooley lakes, Elkhart County, and are now engaged in raising the funds necessary to erect and equip a large factory.

(3) The Monolith Portland Cement Co., with headquarters at Bristol, Elkhart County, has secured by purchase the extensive marl deposits in and about Indiana and Long lakes, north and northwest of Bristol, and will soon erect a large factory, utilizing the water power of the St. Joseph River.

From what has been written it will be seen that the citizens of Indiana have until very recently been exceedingly backward in utilizing the materials suitable for cement making which lie within her bounds. However, the two factories which have just been erected, and those which are proposed promise much for the future. Let us hope that they are but the forerunners, the pioneers of a great industry which shall center about the lakes and marshes of northern Indiana.