PORTLAND CEMENT.

By ERNEST F. BURCHARD.

RAW MATERIALS.

Portland cement, a product obtained by finely pulverizing clinker produced by calcining to incipient fusion a properly proportioned mixture of calcareous and argillaceous materials, is now manufactured in 28 States, those not yet having active plants for making this important structural material being the six New England States, Delaware, the Carolinas, Florida, Mississippi, Wisconsin, Arkansas, Louisiana, the Dakotas, Wyoming, New Mexico, Idaho, and Nevada. The most common raw materials required for the manufacture of Portland cement are high-calcium limestone, marl, "cement rock" (an argillaceous limestone), clay, shale, blast-furnace slag, and boiler ashes of the proper composition. Combinations of two or more of these ingredients are generally used in order to supply the necessary lime, silica, and alumina. Coal, crude petroleum, or natural gas are the fuels used in burning cement in the kilns.

DISTRIBUTION OF PORTLAND CEMENT MILLS.

The natural raw materials for cement are widely distributed, as has been shown by field work done by the United States Geological Survey, and there are few States that do not contain them in sufficient quantity for the manufacture of Portland cement. The distribution of Portland cement mills, however, has been controlled for the most part by markets and transportation facilities, considered in connection with adequate supplies of suitable raw materials and fuel. The large amount of capital required for the construction and operation of a cement mill—ranging from $500,000 for a small plant to five or six times that amount for one of the larger plants—has necessarily restricted the distribution of honestly promoted plants to localities in which the chances for success are greatest. In late years competition in the cement-manufacturing business has been very great, and this has further restricted the establishment of new plants.

If the distribution of cement mills is considered with reference to national defense, a glance at a map showing location of all the mills

in the United States[1] brings out the fact that they are for the most part ideally situated for quickly supplying cement to seacoast cities and yet are generally remote enough from the coast to be immune from direct attack by sea forces. The New England coast points can be advantageously supplied with cement by mills in the Hudson River district of New York; the New York, New Jersey, and Delaware coasts can obtain cement quickly from plants in the Hudson River district and in the Lehigh district of eastern Pennsylvania and western New Jersey; the Maryland and Virginia coasts from plants in those States, one of which is situated near Norfolk, Va.; the Carolina, Georgia, and Florida coasts from plants just west of the Appalachian front in Tennessee, Georgia, and Alabama. Gulf of Mexico points can be supplied by plants in Alabama, Oklahoma, and Texas, only one of which (at Houston, Tex.), is near the Gulf. The Pacific coast is supplied from groups of mills in southern California, around San Francisco Bay, near Portland, Oreg., and near Puget Sound. Cities on the Great Lakes can get cement from many mills in northern New York, western Pennsylvania, northern Ohio, Indiana, and Illinois, the southern peninsula of Michigan, and the mill at Duluth, Minn. Along the Mexican border there are long stretches that are remote from supplies of Portland cement, but mills in southern California, near Phoenix, Ariz., and at El Paso and San Antonio, Tex., should be able to deliver what is needed.

MILITARY IMPORTANCE OF PORTLAND CEMENT.

Portland cement is used mostly as an ingredient in concrete, a mixture of cement, sand, and gravel, broken stone, or slag, and to a smaller extent in mortar and plaster, where it is mixed with sand alone. The cement usually constitutes about one-ninth to one-seventh by volume of the mixture. When sufficient water is added the cement, which is the most finely divided of these materials and consequently most intimately mixed with the others, takes up water of crystallization, forming complex silicates of calcium and aluminum. This crystallization is termed "setting" of the cement, and through its action the sand and gravel or broken stone are bound together and form a rocklike mass. The "setting" of Portland cement takes place as well under water as in the air, and consequently cement is of great value for construction work that is partly submerged. Concrete is employed in the massive form and also reinforced with steel rods, wire, and mesh, thus making possible its use in taller, lighter structures than could be built of solid concrete. Reinforced concrete has been found to offer greater resistance to fire, earthquake, and shock of explosions than other forms of structural materials.

[1] Burchard, E. F., Cement in 1914: U. S. Geol. Survey Mineral Resources, 1914, pt. 2, pp. 221–259, 1915; Cement in 1916: Idem, 1916, pt. 2, pp. 341–375, 1918.

Concrete possesses great adaptability to a wide variety of uses, besides being cheap, easily and quickly handled, sanitary, and durable, and these characteristics taken together render it of great military importance.

Among the military uses to which concrete is put are the construction of armories, barracks, roads, bridges, coast and interior fortifications, gun emplacements, trench linings, bombproof shelters, magazines for explosives, tunnels, retaining walls, sea walls, wharves, dry docks, water reservoirs, aqueducts, sewers, sewage-treatment works, incinerators, stables, floors, roofs, munition-factory buildings, warehouses, fuel-oil tanks, barges, and even in the interior of battleships.

INDEPENDENCE OF THE CEMENT INDUSTRY.

The United States produces more Portland cement than is consumed within the country, and the raw materials are here in abundance. The absolute independence of the industry is assured by the fact that everything needed by a fully equipped cement mill may be obtained in the United States, including pulverizing machinery, pebbles for grinding, and refractory materials for kiln lining. The further possibility of obtaining potash as a by-product at many of the cement mills lends encouragement to the production of cement at such mills, even in times when the profits from cement alone are small.

CONDITIONS IN 1914 AND LATER.

The year 1914 witnessed the first recorded decrease in annual production of Portland cement in the United States. The industry had experienced a remarkable growth during the preceding 10 years, and it was but natural that a slight check should come at this time. The average price per barrel in bulk at mills decreased 7.8 cents in 1914, and the beginning of the war in Europe may be said to have marked a period of depression in the American cement industry, from which recovery was slow at first.

The Portland cement industry showed no noteworthy developments during 1915, notwithstanding the greater activity in the metal industries. In view of the experiences of 1914 manufacturers exercised considerable caution, the result of which was a slight increase in the volume of shipments, a small decrease in the quantity of cement manufactured, and a considerable decrease in the stocks of cement on hand, all indicating a correction of the tendency toward overproduction that has manifested itself at times during the last few years. Prices in 1915 decreased 6.7 cents a barrel below those of 1914, and the estimated consumption of Portland cement per capita in the United States was 0.76 barrel, compared with 0.77 barrel in 1914. The total production in 1914 and 1915 represented from about 69 per

cent to 76 per cent of the apparent actual manufacturing capacity, according to figures reported to the Geological Survey, but it is now believed that the actual capacity was greater than was reported.

In 1916 the conditions were much more satisfactory. At the beginning of the year the industry was already feeling the effects of the gradual revival of activity in construction work, and throughout the year mills in all parts of the United States were busy manufacturing and shipping cement at a rate greater than at any other time since 1913, although labor troubles and lack of freight cars operated as a handicap on production and shipments. Higher prices prevailed, and six new plants reported their first production in 1916, one each in California, Minnesota, New York, Oklahoma, Oregon, and Texas. The plants in Oregon and Texas are close to tidewater, and the one in Texas is unique in using oyster shells as the calcareous ingredient of its raw mix.

As a result of increased business in 1916 stocks of Portland cement were reduced below normal, yet the reserve of more than 8,250,000 barrels on hand at the beginning of 1917 seems sufficient for emergencies. This reserve, however, should be maintained and, if possible, even increased.

The present cement-clinker manufacturing capacity of the mills in the United States is possibly from 30 to 40 per cent greater than the normal consumption, and this surplus capacity seems likely to be maintained through the building of new mills and the enlargement of existing mills. In its bearing on the present situation this condition is encouraging, for there are likely to be large increases in the demand for cement for military purposes for use by the United States as well as by her allies. The utilization of the increased manufacturing capacity is likely also to prove an incentive for gaining new trade in the West Indies, South America, and the Orient if shipping is available.

PRODUCTION, IMPORTS, AND EXPORTS.

The production of Portland cement in the United States from 1912 to 1916 has ranged between 82,000,000 barrels and 92,000,000 barrels annually, an output far exceeding that of any other country. Average prices have been relatively low, ranging between 80 cents and $1.10 a barrel in bulk at the mills, yielding only small profits, but much higher prices are reported to have prevailed in the early months of 1917.

The imports of hydraulic cements into the United States are normally very small, but in 1916 they were almost negligible, having dropped to 1,836 barrels, compared with 42,218 barrels in 1915.

The exports have never been great, the largest quantity—that in 1912—having been only 4,215,532 barrels. In 1914, 1915, and 1916 the exports were respectively 2,140,197, 2,565,031, and 2,563,976 barrels. These quantities represent less than 3 per cent of the total pro-

duction of hydraulic cements in the United States during those years. As recent increases have been due largely to greater exportation to South American countries and the West Indies, it appears that the cement trade is slowly expanding in the direction of greatest promise. The opportunities in these fields were pointed out recently by the Director of the United States Geological Survey.[1] Figure 3 shows graphically the relation between domestic production and consumption of Portland cement in the United States in the last six years.

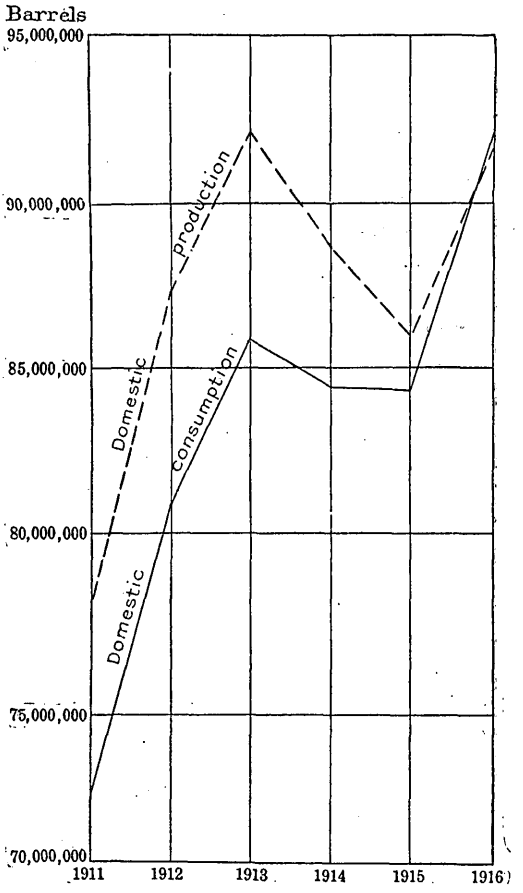

FIGURE 3.—Domestic production and consumption of Portland cement, 1911-1916.

NEEDS OF THE CEMENT INDUSTRY.

Among the present needs of the cement industry is more comprehensive and accurate information with regard to the distribution of materials suitable for concrete aggregates—especially for concrete roads—such as good clean sand, gravel, and stone available for crushing. This information can perhaps best be assembled through cooperation by the United States Geological Survey, the Bureau of Standards, and the Office of Public Roads and Rural Engineering. If funds were available the Survey could make the field examinations, collect samples of materials for test, and prepare maps and descriptions of the nature of the deposits, and the other bureaus could make the requisite laboratory studies of both raw materials and manufactured products.

[1] Smith, G. O., Our mineral reserves: U. S. Geol. Survey Bull. 599, p. 31, 1914.