London) and Medina cement (Isle of Wight) are both quick-setting natural cements.

The artificial cement group includes :

(*a*) Portland Cement { (i) Normal or ordinary. (ii) Rapid-hardening. (iii) White. (iv) Blast-furnace.

(*b*) High Alumina Cement.

(*a*) (i) *Normal or Ordinary Portland Cement.*—Chalk or limestone and clay are the raw materials from which this cement is manufactured (p. 2, Vol. I).

The cement works are generally situated near deposits of these raw materials. A brief description of the manufacture and a diagram of a cement works are given in Fig. 8. The processes include : (1) Excavation and preparation of the materials ; (2) mixing and grinding ; (3) burning ; and (4) grinding.

1. *Excavation and Preparation.*—The chalk is won from the limestone quarry by blasting. Gelignite charges are tamped in 6-in. diameter holes drilled at about 15-ft. intervals and at a distance of 15-ft. from the face (see sketch). On instantaneously firing these charges, huge masses of the limestone, amounting to several thousand tons and varying in size from small fragments to large blocks, are dislodged. This loose stone is discharged into wagons from a mechanical navvy (p. 2) and hauled to the *jaw crusher* into which it is tipped and reduced by two powerful metal jaws to a maximum size of 8-in. cubes. The crushed stone passes on to a moving belt and is conveyed to the *cone crusher* which reduces it down to ¾-in. maximum. This is delivered by a belt conveyor to the limestone silo.

The clay is excavated by mechanically dragging a *scraper-bucket* over the clay field ; this is tipped into a *wash mill* (p. 1), and the washed clay, called *slip*, containing about 60 per cent. of water, is pumped through metal pipes to the *clay slip storage tank*.

2. *Mixing and Grinding.*—The chalk from the silo and the clay slip from the tank enter the *wet grinding mill* at A in the correct proportions (approximately 78 per cent. chalk and 22 per cent. clay). This is a cylindrical mill, 37-ft. long by 7 to 8½-ft. diameter, having a chromium steel lining and divided into three compartments by two slotted diaphragms. About 32 per cent. of the mill is occupied by steel balls graded in diameter from 4 to 3-in. in the first compartment, 2½ to 1½-in. in the middle compartment and 1-in. in the last compartment. The mill is caused to rotate at about 20 revs. per min., and as it rotates, the abrasive action of the balls as they strike against each other and against the metal casing grind the material as it comes between them. Fine grinding and thorough mixing reduce the materials to a creamy consistency, called *slurry*, the bulk of which, after leaving the mill, passes through a fine sieve (having a 0·0035-in. mesh) ; that which fails to pass through the sieve is returned to the mill and re-ground.

After screening, the slurry is conveyed to the *open slurry tank*, which is 66-ft. in diameter and 15-ft. deep, where it is kept agitated by compressed air delivered through perforated pipes at the bottom of the tank. The slurry, now a uniform mixture, is then pumped to the upper or feed end of the kiln.

3. *Burning.*—The kiln is of the rotary type. It is a steel cylinder lined with firebrick, about 300-ft. long and 10-ft. diameter, slightly inclined and mounted on rollers ; it revolves slowly at about 1 rev. per min. The fuel is dry pulverized coal. The raw coal is tipped from the railway trucks at C, elevated to the *raw coal silo*, passed to the *coal mill* where it is finely ground and also dried by hot air conveyed from the kiln by pipe D, elevated to the *pulverized coal hopper* and blown in at the lower or firing end of the kiln—see arrows. The temperature in the lower or burning zone is very intense (a white heat of approximately 2,800° F.) and gradually decreases to 450°–500° F. at the top end, where the gases escape up the chimney stack. Thus the cold slurry, which is fed automatically and continuously, is first dried in the upper zone, and during its passage down the kiln is heated and finally partially fused into clinker. The chalk constituent, as it is heated, is converted into quicklime by the liberation of CO_2 and when subjected to the higher temperature the lime and clay chemically unite to form hard balls (⅛ to ¾-in. in size) of Portland cement, called *clinker*, which is dark brown to black in colour.

This clinker, which is white hot, is cooled as it passes from the kiln at the lower end into drums or cylinders called *coolers*. There are twelve of these coolers, 4-ft. in diameter and at least 20-ft. long, parallel to and attached to the outside of the kiln. A draught of cold air is passed through the cylinders as the clinker gradually gravitates towards and emerges from the lower end on to a belt conveyor which delivers it to the *clinker storage bin* or shed.

4. *Grinding.*—Clinker is fed into the *clinker hopper* by means of an overhead travelling crane grab ; the latter is also used to mix the coarse with the finer clinker. From the hopper the clinker passes to the *combination grinding mill, ball mill* or *dry mill* ; this is of the same size and is similar to the wet mill, it being divided into three compartments which contain graded steel balls. These grind the clinker to a powder which is so fine that at least 90 per cent. of it must pass through a sieve of wire cloth having a mesh of 0·0035-in. square size of opening (see below).

A small quantity, from 1 to 3 per cent., of gypsum (calcium sulphate) is added at B from the *gypsum hopper* which adjoins the clinker hopper. This tends to lengthen the setting time of the cement to suit practical conditions.

The ground cement as it emerges from the dry mill is forced by compressed air up a pipe to silos or bins, each 20-ft. in diameter and about 70-ft. high, and having a capacity of 1,500 tons.

Packing.—The cement from the silos is elevated to a hopper from which it flows to the *packing machine*. The cement was formerly packed into jute bags, but strong paper-valved bags of 1-cwt. capacity are now chiefly used. Each bag is placed by hand on the delivery nozzle of the machine, the cement is automatically weighed as it flows into it, and the filled and sealed bag is discharged and either stacked or placed direct into lorries or trucks. One machine can fill 1,200 bags per hour.

Testing.—The manufacture is closely controlled at each stage, and samples of the clay slip and chalk before they enter the wet mill, slurry after leaving the mill, clinker after leaving the kiln, and cement at the packing machine are taken for laboratory examination.

The cement during and after manufacture is tested in accordance with the British Standard Specification for Ordinary Portland and Rapid-hardening Portland Cements, No. 12—1940.[1] This specification includes the following tests with which Portland cement must comply : (*a*) Fineness, (*b*) chemical composition, (*c*) strength, (*d*) setting time and (*e*) soundness. The following are brief particulars of these :—

(a) *Fineness.*—This is estimated by sieving for fifteen minutes a sample (about 4-oz.) of the cement on a No. " 170 " (0·0035-in. mesh) British Standard sieve, when the residue for ordinary Portland cement shall not exceed 10 per cent. As a general rule the finer the cement the more rapid the strength development of the concrete.

(b) *Chemical Composition.*—This clause in the specification limits the proportion of lime to the silica, alumina and iron oxide, and the ratio of the percentage of iron oxide to that of alumina. It also specifies the maximum percentage of insoluble residue (1 per cent.), magnesia (4 per cent.) and sulphur (2·75 per cent.), in addition to limiting the loss on ignition to 3 per cent.

[1] Published by the British Standards Institution, 28 Victoria Street, London, S.W.1, at 2s. net.