remains plastic for a short while. The water combines chemically with the grains of cement to form hydrates. This is known as *hydration*. As this proceeds, the plasticity gradually disappears and the cement stiffens or *sets*. The cementing material between the particles of cement increases in amount, causing the mass to gain in strength and *hardness*, and this hardness increases for some considerable time after it has set.

The specification refers to " initial set " and " final set." Regarding the former, it is essential that the cement shall set slowly at first to allow time for the mixing and placing in position of the concrete, and to ensure thorough adhesion between adjacent batches of concrete. It is equally important that the concrete shall harden quickly after its initial set in order that it may be loaded as soon as possible and (in the case of reinforced concrete) permit of the early removal of any formwork or shuttering (temporary timbering) which may be supporting it.

According to the specification, the initial setting time for normal setting cement shall be not less than thirty minutes and the final setting time not more than ten hours. If a quick-setting cement (see next column) is required, the initial setting time is reduced to not less than five minutes, and the final setting time to not more than thirty minutes. The Vicat apparatus, shown at D, Fig. 9, is used to determine the initial and final setting times of cement. A brass cylindrical mould, approximately 3-in. dia. and 1½-in. deep, is placed upon a metal plate and filled to the top with neat cement to which sufficient water has been added to make it plastic. The filled mould is placed on the base as indicated by broken lines. The initial set is measured by means of a needle having a flat end, 0·039-in. (1-mm.) square, which is screwed to the bottom of the rod in place of the final setting needle shown. The pin is withdrawn and the rod is lowered until it touches the smooth surface of the cement, when it is quickly released and allowed to penetrate the cement. This is repeated at intervals on different parts of the specimen until the needle fails to pierce it completely. The time which has elapsed between the addition of the water and this partial penetration of the needle is called the initial setting time and, as already stated, must not be less than thirty minutes for normal setting cement (or five minutes for quick-setting cement). The final setting time is determined in a similar manner, the initial setting needle being replaced by the final setting needle shown. The latter, of the same shape and section as the former needle, has a metal fitting attached at the end ; the base of the fitting has a raised rim which is about 0·02-in. (½-mm.) above the end of the central needle. The cement is considered to be finally set when, on a gentle application of the needle, the central flat point makes an impression on it, but the raised rim fails to do so. This final setting time must not exceed ten hours for normal-setting cement or thirty minutes for quick-setting cement.

(e) *Soundness.*—Unsound cement has a tendency towards excessive expansion. Sound cement is relatively free from this tendency and its volume remains constant. Most serious defects in cement products are caused by expansion which takes place during setting and may continue for some considerable time. Thus, reinforced concrete made of unsound cement may crack and disintegrate to such an extent as to permit the entrance of moisture and cause corrosion of the exposed steel. The soundness test which appears in the standard specification is therefore very important.

This soundness or expansion test is carried out in the Le Chatelier apparatus illustrated at F, Fig. 9. This is a brass split cylindrical mould having an indicator attached on each side of the split. The mould, resting on a glass plate and held together with the split edges touching, is completely filled with neat cement gauged with just sufficient water to make it plastic, and covered with another glass plate which is held down by a small weight. It is at once immersed in water (temperature 58° to 64° F.) and left for twenty-four hours. It is taken out, the distance W between the indicators is measured, the weighted mould is again immersed and then boiled for three hours. The mould is removed and, after cooling, the distance between the points is again measured. The difference between the two measurements indicates the expansion of the cement and shall not exceed 0·4-in (10-mm.).

Good cements will show little (not more than 0·04-in.) if any expansion. The expansion of poor cements is often due to the presence of excess gypsum and other sulphates. The boiling water accelerates the reaction and resultant expansion.

A simple but effective test (not mentioned in the specification) is the *hot-pat test*. Water is added to neat cement and thoroughly mixed to a plastic condition. This is worked to the shape of a ball, placed on a piece of glass which is tapped on the bench until the cement flattens out to the shape of a disc about 3-in. in diameter, a little more than ¼-in. thick at the centre and tapering to a knife-edge at the circumference. The surface is then smoothed over with a knife. After being covered over with a damp cloth and allowed to harden for twenty-four hours, the pat is boiled in water for four or five hours. If the cement is unsound, radial cracking (especially at the edges) and distortion will appear, due to expansion ; the edges may curl up and surface flaking may appear. A pat of sound cement will remain unaltered after this treatment, although fine shrinkage cracks may appear.

The *cold-pat test* is similar to the above, except that the pat is not boiled but simply immersed in cold water for twenty-four hours before examination.

(*a*) (ii) RAPID-HARDENING OR HIGH-EARLY-STRENGTH PORTLAND CEMENT.—This is true Portland cement, and, as its name implies, its chief characteristic is the comparative rapidity with which it gains in strength in the early stages of hydration (see Table II, p. 34).

The B.S.S. No. 12—1940, already referred to, applies to this cement. Whilst the residue of ordinary cement on a 170 sieve shall not exceed 10 per cent. (see p. 22), that of rapid-hardening cement shall not exceed 5 per cent. The ultimate tensile stress shall be not less than 300-lb. per sq. in. after one day and 450-lb. per sq. in. after three days. The compressive strength shall be not less than 1,600-lb. per sq. in. after one day and 3,500-lb. per sq. in. after three days. The initial setting time shall be not less than five minutes and the final setting time shall be not more than thirty minutes. These requirements should be compared with those stated in respect to ordinary Portland cement.

Rapid-hardening cement can be usefully employed in cold weather, as it is less liable than ordinary cement to damage from frost. It is preferred to ordinary cement in the construction of concrete roads, as it can take traffic within a few days, whereas concrete composed of ordinary cement should be left for twenty-eight days before roads are opened to heavy traffic. This advantage also applies to reinforced concrete floors, etc., made of rapid-hardening cement, as the lapse of time before the removal of the temporary timbering (formwork) and the application of loads is considerably reduced. The cost of rapid-hardening cement is slightly more than that of ordinary Portland cement. " Ferrocrete " and " Vitocrete " are some of the well-known brands of rapid-hardening cement.

(*a*) (iii) WHITE PORTLAND CEMENT.—The chemical composition and characteristics of white Portland cement are similar to those of ordinary Portland cement, except that the latter is of a grey colour. The colour of white cement is due to the raw materials used and the special precautions taken in its production. The materials are pure limestone and china (white) clay, the iron oxide content (which imparts the grey colour to ordinary Portland cement) being less than 1 per cent. The cement must not come into contact with iron or steel during its manufacture, the kiln is lined with special fireclay blocks, and oil is generally the fuel used. Aggregates used with white cement should