bedding planes when it becomes frozen, and thus disintegration of the stone occurs. Copings, unprotected cornices and string courses, walls of unsuitable materials and inferior workmanship below the ground level, and retaining walls are most vulnerable to damage by frost action. Blocks of face-bedded stone are particularly liable, as any water penetrating the stone and becoming frozen will cause patches of the skin to spall off.

7. *Corrodible Metal Fastenings*.—Reference is made on p. 52, Vol. I, to the damage caused to stonework which is secured with corrodible metal, such as wrought iron. The expansion which occurs when embedded wrought iron corrodes is sufficient to split huge blocks of the stone, such as cornices, copings and upper spire stones.[1] Metal which does not rust, such as bronze, gun-metal and copper, should be used for these fastenings.

PRESERVATION.—The best method of preserving stone is by washing or steam cleaning (see p. 98). Most so-called " preservatives " have proved to be unsatisfactory.

TESTS APPLIED TO STONES

It is recognized that the most reliable indication of the durability of a stone required to withstand certain atmospheric conditions is obtained by a careful inspection of that used in the construction of buildings which have been subjected to similar exposure for a lengthy period. Such is not, however, a conclusive guide, as the quality of stone obtained from different parts of a quarry may vary considerably, and it does not therefore follow that the characteristics of recently won stone are similar to that obtained from older workings in the same quarry and which was used for the inspected buildings. Further, the quality of stone from a new quarry cannot be judged in this manner. Laboratory tests are therefore valuable for supplying information which could only be otherwise obtained by trial and error methods.

The following are tests which may be carried out for estimating the durability of stone : (1) Rate of water absorption or permeability, (2) percentage porosity, (3) saturation coefficient, and (4) resistance to frost. They provide information which can be compared with stones whose durable qualities and other properties are known, and whilst such comparative tests are not decisive, they do give data which may be of value when selecting a stone for a specific purpose. Students should refer to the footnote on p. 14 for brief definitions of absorption, permeability and porosity.

1. *Rate of Water Absorption or Permeability Test*.—This is described on p. 14, the brass cover being fitted to the stone specimen whose four vertical faces are rendered impermeable by the application of wax. As already explained, the test conditions are not likely to be exceeded, even in the most exposed positions, by those met with in practice.

2. *Percentage Porosity Test*.—In order to understand the significance of the expression " percentage porosity," the student should revise the definitions of *bulk density* and *solid density* which he would have considered in his study of Building Science and which for convenience are repeated here.

Density (in lb. per cubic foot) $= \dfrac{\text{weight (in lb.)}}{\text{volume (in cubic feet)}}$; therefore the *bulk* or *total density* (in lb. per cubic foot) $= \dfrac{\text{weight (in lb.)}}{\text{bulk volume (in cubic feet)}}$. If the specimen to be examined is of irregular shape, the bulk volume is obtained by using an apparatus such as the *overflow tank* shown at A, Fig. 35. The specimen is carefully lowered into the tank which has been previously filled with water to the " weir " level indicated ; the water displaced passes from the outlet into a vessel of convenient size and transferred to a glass measuring cylinder ; this gives the volume of the water, which is equal to that of the specimen.

The solid or powdered density (in lb. per cubic foot) $= \dfrac{\text{weight (in lb.)}}{\text{solid volume (in cubic feet)}}$.

Actually, the solid density of most stones, in addition to bricks and concretes, is approximately the same, namely, 166-lb. per cub. ft. The adoption of this figure therefore simplifies the routine, as it obviates the necessity of powdering the specimen and obtaining its volume.

The *percentage porosity* is found after the bulk and solid densities have been determined, thus :

$$\text{Percentage porosity} = \frac{\text{volume of voids}}{\text{bulk volume}} \times 100$$

$$= \frac{\text{bulk volume} - \text{solid volume}}{\text{bulk volume}} \times 100$$

$$= \left(1 - \frac{\text{solid volume} \times \text{weight}}{\text{bulk volume} \times \text{weight}}\right) 100$$

$$= \left(1 - \frac{\text{solid volume}}{\text{weight}} \times \frac{\text{weight}}{\text{bulk volume}}\right) 100$$

$$= \left(1 - \frac{\text{bulk density}}{\text{solid density}}\right) 100$$

$$= \left(1 - \frac{\text{bulk density}}{166}\right) 100.$$

The percentage porosities of the stone specimens (approximate size, 5-in. by 3-in. by 2-in.), given in Tables V and VI can be determined by using this formula. Thus, taking the Appleton stone which heads the list in Table V, the bulk density being 148-lb. per cub. ft. the percentage porosity $= \left(1 - \frac{148}{166}\right) 100 = 11$ approx., the figure given in the table.

3. *Saturation Coefficient Test*.—Damage caused by frost is referred to on p. 98. Very porous stones will absorb more water than others less porous and are therefore more vulnerable to damage due to frost action. If the voids are completely filled with water and this water freezes, the resulting pressure will tend to disrupt the cell walls by internal pressure. If, however, the interconnected pores (see p. 14) are only partly filled with water, there may be sufficient space within them to allow for this expansion, and damage to the stone structure will not occur. Hence the ratio of water absorbed to the volume of void space may be taken as a measure of the capacity of the stone to resist frost action ; this ratio is known as the *saturation coefficient*. It is usually expressed as follows :—

$$\text{Saturation coefficient} = \frac{\text{water absorbed after twenty-four hours' soaking}}{\text{total water absorption after five hours' boiling}}.$$

[1] The apex of a stone spire consists of blocks of stone which are usually connected together by a central vertical metal rod. It is a fairly common experience to find that these blocks have developed cracks, and investigations have shown that the defects were caused by the corrosion of the rods. The work of restoration is costly, as scaffolding has to be erected, and the whole of the defective stonework must be removed and replaced with new blocks which are " threaded " over a non-corrodible vertical rod.