crete is aggravated by poor and inefficient field work. Even if the added expense could be afforded of screening and remixing the aggregates so as to secure proper granulometric composition to give the density required to make untreated concretes impermeable, it is seemingly often a commercial impossibility on large construction to obtain workmanship even approximating that found in laboratory work.

Addition of Foreign Substances.—The committee found that, in consequence of the conditions outlined above, substances calculated to make the concrete more impermeable, either incorporated in the cement or added to the concrete during mixing, are often used.

The committee had investigated a sufficient number of the special waterproofing compounds on the market, as well as the use of certain very finely divided mineral products, such as finely ground sand, colloidal clays, hydrated lime, etc., to form a general idea of the value of the different types. It reported that:

(a) The majority of patented and proprietory integral compounds tested have little or no immediate or permanent effect on the permeability of concrete and that some of these even have an injurious effect on the strength of mortar and concrete in which they are incorporated.

(b) The permanent effect of such integral waterproofiing additions, if dependent on the action of organic compounds, is very doubtful.

(c) In view of their possible effect, not only upon the early strength, but also upon the durability of concrete after considerable periods, no integral waterproofing material should be used unless it has been subjected to long-time practical tests under proper observation to demonstrate its value, and unless its ingredients and the proportion in which they are present are known.

(d) In general more desirable results are obtainable from inert compounds acting mechanically than from active chemical compounds whose efficiency depends on change of form through chemical action after addition to the concrete.

(e) Void-filling substances are more to be relied upon than those whose value depends on repellent action.

(f) Assuming average quality as to size of aggregates and reasonably good workmanship in the mixing and placing of the concretes, the addition of from 10 to 20 per cent. of very finely divided void-filling mineral substances may be expected to result in the production of concrete which under ordinary conditions of exposure will be found impermeable, provided the work joints are properly bonded, and cracks do not develop on drying, or through change in volume due to atmospheric changes, or by settlement.

External Treatment.—While external treatment of concrete would be necessary if the concrete itself, either naturally or by the addition of waterproofing material, was impermeable, it was found in practice that in large construction, no matter how carefully the concrete itself has been made, cracks are apt to develop, due to shrinking in drying out, expansion and contraction under change of temperature and moisture content, and through settlement.

It is, therefore, often advisable on important construction to anticipate and provide for the possible occurrence of such cracks by external treatment with protective coatings. Such coating must be sufficiently elastic and cohesive to prevent the cracks extending through the coating itself. The application of merely penetrative void-filling liquid washes will not prevent the passage of water due to cracking of the concrete. The committee therefore, divided surface treatment into two heads:

(a) Penetrative void-filling liquid washes.

(b) Protective coatings, including all surface applications intended to prevent water from coming in contact with the concrete.

While some penetrative washes may be efficient in rendering concrete waterproof for limited periods, their efficiency may decrease with time, and it may be necessary to repeat such treatment. The committee, expressed its belief that the first effort should be made to secure a concrete that is impermeable in itself and that penetrative, void-filling washes should only be resorted to as a corrective measure.

While protective extraneous bituminous or asphaltic coatings are unnecessary, so far as the major portion of the concrete surface is concerned, provided the concrete is impermeable, they are valuable as a protection where cracks develop in a structure. It therefore recommended that combination of inert void-filling substances and extraneous waterproofing be adopted in especially difficult or important work.

Bituminous or Asphaltic Coatings.—Considering the use of bituminous or asphaltic coatings, the committee found that:

(a) Such protective coatings are often subject to more or less deterioration with time, and may be attacked by injurious vapors, or deleterious substances in solution in the water, coming in contact with them.

(b) The most effective method for applying such protection is either the setting of a course of impervious brick dipped in bituminous material into a solid bed of bituminous material or the application of a sufficient number of layers of satisfactory membranous material cemented together with hot bitumen.

(c) Their durability and efficiency are very largely dependent on the care with which they are applied.

Such care refers particularly to proper cleaning and preparation of the concrete to insure as dry a surface as possible before application of the protective covering, the lapping of all joints of the membranous layers, and their thorough coating with the protective material. The use of this method of protection is further desirable because proper bituminous coverings offer resistance to stray electrical currents.

Richer Mixtures.—So far the committee had considered only concretes of the usual proportions, namely, those ranging from 1 cement, 2 sand and 4 stone, to 1 cement, 3 sand and 6 stone. It was suggested that impermeable concretes could be assured by using mixtures considerably richer in cement. While such practice would probably result in an immediate impermeable concrete, the advantage is believed to be only temporary, as richer concretes are more subject to check cracking and are less constant in volume under changes of conditions of temperature, moisture, etc. Therefore, the use of more cement in mass concrete would cause increased cracking, unless some means of controlling the expansion and contraction be discovered. With reinforced concretes the objection is not so great, as the tendency to cracking is more or less counteracted by the reinforcement.

It was also suggested that the presence in the cement of a larger percentage of very fine flour might result in the production of a denser and more impermeable con-