Chemistry of Building Materials

AT the meeting on September 7 of Section B (Chemistry) of the British Association, there was a symposium on "The Chemistry of Building Materials". After an introduction by Dr. R. E. Stradling (director of the Building Research Station), papers were presented by Dr. F. M. Lea (Building Research Station) on "Some Problems in the Study of Hydraulic Cements", Dr. J. S. Dunn (Imperial Chemical Industries, Ltd.) on "Calcium Sulphate Plasters; Setting, Retarders and Accelerators", Mr. F. H. Clews, Mr. H. H. Macey and Dr. G. R. Rigby (British Refractories Research Association) on "Some Important Properties of Clay", and Dr. D. G. R. Bonnell (Building Research Station) on "Some Problems connected with Porous Building Materials".

Building presents an excellent example of a traditional industry in the stage of transition to an applied science. It is an industry founded originally on craft and based on rules of experience which have become enshrined in traditional methods. To the older building materials such as timber, stone, burnt clay and lime, there has been added in modern times a host of new products, whilst the demand for speed and economy in building has resulted in numerous changes in methods. These changes have often been in the nature of extensions and modifications of traditional processes, but they have been made without that full knowledge of the reasons for the success of the traditional methods which is necessary if development is to have a sure basis and to be other than the slow and costly traditional method of trial and error. Modern conditions have necessitated, therefore, not only the examination of the newer materials and processes, but also the study of the traditional materials and of the reasons for the success of the traditional methods.

This is well exemplified in the craft of the plasterer. The production of lime was formerly a local industry, and the craft by long experience had become adapted to the properties of the local materials. The modern development of large-scale production has led to the wide distribution of materials which, though outwardly similar, differ in properties from those to which the craftsman was accustomed. Calcium sulphate plasters have been added as an additional plastering medium, but materials of this class, differing widely in properties, and in the methods necessary for their successful handling, are distributed under trade names giving no clue as to the type to which they belong. The substitution of Portland cement mortar for lime mortar in rendering and stucco, again without adequate appreciation of the very different properties given to the finished product, has been a very common cause of trouble.

As was pointed out by Dr. Stradling, the craftsman in lime and plaster controls a chemical reaction of which he knows nothing. While working with materials in which he had long experience, the craftsman could produce excellent work; with materials of different physical properties and rates of reaction, however good these materials might be, there entered factors to which he was unaccustomed, and of which he had no warning, and his craft suffered in consequence.

The problems in building to-day are, however, not only due to insufficient knowledge of the fundamental properties of its materials of construction, but also, and in considerable degree, to insufficient dissemination of the existing knowledge among architects, builders, engineers and craftsmen. Whilst research on materials is now proceeding at a rapid rate in many countries, the need for further education in the building industry is only too clear.

The discussion at the meeting of Section B could inevitably only cover a small part of the field indicated by its title, but it sufficed to bring forward many interesting problems.

Apart from the metals and igneous rocks, all building materials are porous and capable of absorbing water to some extent. Changes in moisture content, not only on first drying, but also in subsequent use, produce accompanying changes in volume and in other physical properties such as strength and elasticity, while the movement of water, carrying soluble salts in solution, gives rise to surface efflorescence and to decay of masonry and brickwork. The change in volume is responsible for much of the cracking found in buildings. In practice it is relieved to some extent by the ability of materials to creep, or undergo plastic deformation under load. Though much work has been done on shrinkage and creep, there is still need for further study of moisture movements under conditions of restraint, such as normally occur in building. The general phenomenon of volume change in porous solids has as yet interested chemists relatively little though it offers a promising field for research. The work of Meehan and Bangham on the expansion of charcoal by sorption of gases and vapours is suggestive in this connexion.

Calcium sulphate plasters can be grouped generally into the hemihydrate and the anhydrite types, the latter being produced by the burning of gypsum at relatively high temperatures or from the natural mineral. The system calcium sulphate - water is of the simplest binary type, but despite much work since Lavoisier's original contribution in 1765, the problem of the dehydration products of gypsum has never appeared fully solved. It has usually been considered that the partial dehydration of gypsum results in the formation of the hemihydrate, $CaSO_4.\frac{1}{2}H_2O$, but Dr. Dunn reported that the crystal form of this compound remains unaffected, with but minor changes in the lattice constants, with water contents ranging from 0 to 0·65 molecules of water. It is considered probable, therefore, that there is a zeolitic series with $3CaSO_4.2H_2O$ and $CaSO_4$ as end members. Plasters containing the so-called hemihydrate usually require to be retarded as otherwise their rate of set is too rapid for normal use in building. Two types of retarder can be distinguished, one reducing the rate of nucleus formation and the other acting similarly, but, in addition, modifying the habit of the gypsum crystals, giving a relatively slower rate of growth along the *c* axis. The rate of set of anhydrite plasters is very slow and, in practice, an addition of an accelerator is required. In general the hydration is accelerated by sulphates of the alkali and other metals, but the most effective catalysts are those combining an alkali metal sulphate with the sulphate of another metal such as zinc, the effect being more than additive and an optimum ratio existing for the two sulphates. The alkali metals accelerate the growth of gypsum crystals most at right angles to the *c* axis, while zinc sulphate is more specific for growth parallel to that axis. This observation takes the explanation of the action of a two-component catalyst one stage forward, but the problem of how each catalyst stimulates crystal growth still remains.

Though the most obvious property required in a cement is that of developing strength, in practice this presents few problems compared with those arising from volume change and physical and chemical decay. The heat of hydration of Portland cement, which may amount to a hundred calories per gram, is a source of considerable trouble in concrete structures of large mass. The internal temperature in concrete dams, for example, may rise as much as 50° C. above the original temperature of the materials, and the thermal contraction which takes place during subsequent cooling is the main cause of cracking in such structures. The production of cements with a reduced heat of hydration, and their utilization in recent work, such as Boulder Dam on the Colorado River, U.S.A., can be traced back to the much increased knowledge of the constitution of Portland cement which has resulted from phase equilibrium studies on many of the oxide systems involved.

The relative properties of vitreous and crystalline phases of the same gross composition is a matter of much interest in cement technology at the present time. During the burning of Portland cement, some 20–30 per cent of the mass passes into the liquid condition, but the extent to which this liquid crystallizes on cooling, or supercools to form a glass, probably varies considerably. There is evidence that unexplained differences in properties of cements of similar composition and fineness may have their origin in variations of this kind.

Clay is amongst the oldest of the raw materials of building and it has been successfully moulded, burnt and used for some thousands of years without any scientific knowledge of its chemical constitution or physical properties. A certain degree of control was, however, formerly exercised by Acts of Parliament. In 1477, in the reign of Edward IV, an Act required that the clay should be dug before November 1, turned over before February 1 and not used before March 1. Even so late as the reign of George III, there came an added requirement that the clay should be turned between February 1 and the time of moulding of the bricks. The reduction or, in some cases, entire elimination of the time of weathering of the raw clay, together with the speeding-up of drying and other processes, have created many new technical problems. The large-scale production of burnt clay products demands, therefore, if it is to be conducted on economic lines, a degree of control both of materials and processes which was quite foreign to the older small-scale industry.

The mineralogy of raw clay has made striking advances in recent years, but the chemical changes which occur on burning are still a matter of controversy. Plasticity, that physical property by which clays are characterized, remains a much confused subject. In many of the experimental methods used for its determination in the clay industry, properties other than plasticity enter, and a return to methods which are fundamentally simple, such as the measurement of deformation in torsion or tension, appears necessary. Problems of drying play a large part in manufacture, and most manufacturers use unnecessarily long drying periods as an insurance against losses by cracking. This could be avoided by the application of adequate knowledge of the properties of a clay. The temperature of drying is important, there being a temperature at which the safe rate of drying is a maximum ; the tendency to crack is greater above and below this temperature. It appears that the decrease in viscosity of water with rise in temperature is offset at the higher temperatures by the decrease in the tensile strength of the clay.

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