FACTORS AFFECTING THE LIFE OF CONCRETE STRUCTURES.

No structure is permanent, in the strict sense of the term, no matter what the constituent material or materials may be. The degree of durability is accordingly an item of great importance in the consideration of all materials of construction. In the majority of cases the most used have achieved their rank by virtue of their resistent qualities, and their general use has resulted from carefully gleaned knowledge and proven skill on the part of engineers of experience.

In this respect the acceptance of concrete, since the time when Portland cement came to be regarded as one of the principal construction materials, was viewed with distrust by many a doubting Thomas. It cannot be denied that the doubts concerning its permanence and reliability were justified, so many early failures occurred, due to crude preparation of cement, rule-of-thumb methods, and inadequate knowledge of the cementing qualities of the constituents of the resulting mixture. Each failure added weight to criticism and incentive to critics.

But concrete has survived; there are surely few engineers who do not rank it among the most resistent structural materials known. It is needless here to review the preponderous investigation and study through which only it gained its worthy classification.

The probable life of concrete structures is a subject having to do with the possible causes of their destruction, and a consideration of the latter serves well as a basis for an estimation of the former. Mr. Bertram Blount, of London, Eng., addressed the International Engineering Congress, in September last, upon the probable and presumptive life of concrete structures made from modern cements, outlining in the case of both plain and reinforced concrete the chief causes which determine their life. In the majority of cases what affects plain concrete affects reinforced concrete and vice versâ; but the probable life of reinforced concrete involves a consideration of the steel severally and jointly, in addition to that of the concrete.

The possible causes of destruction of ordinary concrete as distinguished from reinforced concrete are listed by Mr. Blount as follows: Bad cement, bad aggregate, bad proportions, bad mixing, bad workmanship, bad design, external violence, fair wear and tear, action of saline solutions, action of acids, electrolysis; and all the foregoing causes of destruction are operative towards reinforced concrete as well as plain concrete. In addition there are: (1) corrosion of reinforcement direct or by electrolysis. (2) cracking due to monolithic character or possibly to stresses between the concrete and the reinforcement.

With these causes Mr. Blount's paper deals in part as follows:—

The best modern cement made of suitable raw materials, intimately mixed, thoroughly burnt and finely ground, is as dependable a material as can be prepared until the time comes when all cement is made by fusing the constituents in a sort of super-blast-furnace, a method tried some years ago, and one which is regarded by many as an advance on the present rotatory process. But these conditions of excellence are not always fulfilled. Chiefly because of the endeavor to obtain large outputs of cement per unit of plant the control of proportions is sometimes inaccurate, the burning not uniform and the grinding not only coarser than is desirable but "gritty." Such cement fails in respect of the first quality absolutely essential to the stability of any structure of which it forms part—it is not sound. Quite useless is it to say that such unsound cement has been used and the structures made with it are standing; the point of interest is how many have fallen down. Further, there is the pregnant question whether a buyer will not insist on a material which is certain to be free from vice, or whether for the convenience of the seller he will trust to luck. Generally, the man who pays can and will get what he wants. It may be confidently said that, given careful manufacture, rigid inspection and thorough testing to a searching specification, modern cement can be obtained free from all inherent vice, and that structures of which it forms part will not be brought to a premature end by internal treachery.

Bad aggregate is a fruitful source of trouble, and, simple as it is in a specification to say that the aggregate shall be "suitable, clean, sharp, well washed," and so on, it is not always easy to get such an aggregate at a reasonable price. Local material must almost always be used, and it may be of the most diverse description. The one property, which is indispensable, is that it must be chemically stable under the conditions in which it is to be used. It does not follow absolutely that the aggregate shall be stable *per se*, though it is much better that it should be; there are materials which oxidize, or which weather, that may on occasion act as a serviceable aggregate, but only urgent necessity will sanction their use. Thus, in general, rocks containing pyrites should be avoided, but it would be pedantic to reject a granite or a hard limestone on the sole ground that specks of pyrites are present. Not merely the amount and size of the enclosed pyrites should be considered; naturally a rock containing marcasite is *ipso facto* suspect. In such cases, petrological methods of examination should be used. Similarly, slags, such as copper slag containing much ferrous silicate, may well be used if their silica content is high enough; generally, such slags lie in dumps, and have so lain for years, and their behavior during exposure to weather is a great guide. The same remark applies to blast furnace slag. Analysis is very helpful if the results are carefully interpreted, but the behavior of the material on the dump is even better. Speaking generally, substances containing sulphates or sulphides, capable of oxidation under working conditions, are so dangerous that their use should not be tolerated, and the need of this restriction can be the better realized when it is remembered that 1% of SO_3, calculated on the aggregate, may mean 5% or more on the cement. Perhaps, of all the materials used as aggregate, the most dangerous is coke breeze. The danger lies in the fact that some samples contain an abundance of sulphates, and, on account of the porous nature of the breeze, these are readily extracted, and do their deadly work on the cement. No sample of breeze should be used as an aggregate unless it has been analyzed and tested. Aggregate may be mechanically as well as chemically bad, but exactly how to define that badness is not easy. Such obvious defects as softness, cracks or excessive smoothness need no more than mention, but how far a "dirty" aggregate carries its own condemnation, is a more difficult matter to decide. It may safely be said that clayey matter round the coarser lumps will prevent a proper bond, but the effect of a moderate amount of clayey matter in the sand is not necessarily harmful. Like most practical things, it is eminently a matter to be settled by trial, and test cubes of the proposed aggregate compared with similar cubes of some aggregate recognized as a standard, such as granite chips and clean sand, will decide the point. Four other causes of short life for a concrete structure, *viz.*, bad proportions, bad mixing, bad workmanship and bad design, call for little comment except this, that evil as are all these for ordinary concrete, they are ten times worse for reinforced concrete, because, while ordinary concrete is generally used in considerable masses, a structure of reinforced concrete is a more delicate affair in which all