four sources of mischief have a greater say. Particularly is this the case in respect of bad proportions and bad workmanship. All reinforced concrete should be as nearly impervious as can be contrived, as it is of the utmost importance to protect the reinforcement; and although it is true that iron is protected in an alkaline medium, yet reliance should not be placed on that alone; it is far sounder practice to make concrete of all kinds, and especially reinforced concrete, as nearly watertight as is practically possible.

The life of concrete structures may be shortened by causes which are external to itself. The violence of wind, wave and earthquake, the effect of the subsidence of the soil, etc., will destroy any structure however well made. But, in practical affairs, one does not legislate for the infinite, and is content to make structures so good that ordinary natural violence will have little effect. The simplest and most important case is that of making harbors which must resist all these natural forces. Thanks to our harbor engineers, a fair degree of success has been attained, largely empirically. Putting aside for the moment the question of the quality of the cement, over which they had little control, they understood in some degree that the concrete must be strong and dense, and, by proportioning the aggregate, obtained a material which complied fairly with these requirements. But accurate measurement of voids and the knowledge that ordinary good concrete of about 1 : 6 may, and often does, contain 30% of voids, have not been so generally utilized as to prevent failures which are traceable to erosion and corrosion by the sea. It is not enough that a block of concrete should be strong; it must be as nearly as possible impervious and impenetrable. The need for these qualities in reinforced concrete is vastly more urgent; reinforced concrete has a vulnerable skeleton, and its exoskeleton must be perfect. Fair wear and tear is only a mild case of external mechanical violence, and need not be further considered.

A particular form of external violence is the action of fire in any serious conflagration. It has been frequently stated that concrete structures are substantially fireproof, and, as far as inflammability is concerned, this is true, but it must be remembered that set cement is a substance containing combined water and carbonic acid, and that these are expelled at a comparatively moderate temperature. It might be naturally supposed that a structure exposed to fire would be seriously weakened by the decomposition of the essential cementitious constituents, and this surmise is, of course, correct. But, for all that, the amount of deterioration is less than one would think likely, and the appended table shows the results of a few experiments made on a cement mortar in the usual proportions of 3 to 1 by weight.

Test pieces* were heated for 1 hour at the following temperatures:—

Temperature Cent.	% Loss calculated on cement.	
100	5.32	No appreciable effect.
200	14.12	No appreciable effect.
300	16.68	No appreciable effect.
400	16.56	No appreciable effect.
500	17.96	No appreciable effect.
600	21.92	Sound—weak at edges.
700	22.24	Sound—friable.
800	25.68	Sound—distinctly friable.
900	25.08	Sound—distinctly friable.
1,000	24.36	Sound—very weak.
1,100	25.40	Sound—very weak.

*Composition of test pieces, 3 standard sand to 1 Portland cement by weight. Age 3 months.

In no case, even at the highest temperature, were there any signs of disintegration or flying, and no mechanical loss occurred during the test.

It will be seen that up to a temperature of 500° C. there is no appreciable alteration, and even beyond that the test pieces show considerable stability, a circumstance which is reassuring from the point of view of that most important question of fireproof construction. Before accepting such a conclusion unreservedly, however, it must be remembered that the tenderest members of reinforced concrete are the steel reinforcements, and that if the heat penetrates the envelope of concrete sufficiently to soften the steel, the destruction of the building will occur exactly as in the case of an ordinary steel frame building.

Shortening of the life of concrete by chemical action of external origin, which for the purpose of a list have been put under three headings, may be conveniently considered under one. A great number of investigators have applied themselves to determine what is the probable or presumptive life of concrete, and, on account of the practical importance of the problem, have chiefly concerned themselves with the action of one saline solution. The destruction of concrete by seawater has always been, since the days when Portland cement first began to be used, a matter of much concern to engineers engaged in maritime works, and, even as lately as 30 years ago, much confusion of mind existed. Thus, because magnesia was found to be a predominant constituent of various incrustations and exudations on sea work, the erroneous conclusion was drawn that it was derived from the cement, and anxiety was felt concerning what could be considered the permissible limit for magnesia in cement. Of course, it is now common knowledge that the magnesia found has been formed from the seawater by the action on it of the lime of the cement, and that the small quantities of magnesia normally present in Portland cement of good quality are without influence in these cases of injury.

It may be accepted that the heaviest and most important work is block work, and in this case the cement has ample time to harden before it is exposed to the sea. From consideration of expense, it is sometimes desired to use a comparatively poor mixture, but the saving is sometimes dearly bought. In fact, the one indispensable condition for a long life for work exposed to the sea is the denseness and imperviousness of the concrete, and this is difficult to secure unless the cement is used liberally. It is impossible to fix a proportion, as that will depend on the aggregate. Every case must be judged for itself, the voids determined experimentally and enough cement used to fill them. Whenever any good form of puzzolanic material, such as trass and the like, is available it should certainly replace a part of the sand, for its use in forming a calcium silicate with the lime, normally set free during the setting of Portland cement, is undoubtedly of value, much conducing to the obtainment of that imperviousness which is a necessary condition for sound and lasting work. It should not be overlooked that any puzzolanic material can fulfil two functions. If coarsely ground, it acts partly as an aggregate like sand, and it is only when ground as finely as the cement itself that its full activity as a cementitious material comes into play. There is no objection to the use of coarse puzzolana if the supply is abundant and local, but, if it has to be brought from a distant place, it is evidently uneconomical to use part of it for a purpose equally well fulfilled by an inert material like sand. In some cases, it might be desirable to grind the puzzolana and cement together to an equal fineness. This plan has been objected to by many engineers as being equivalent to an adultration of the cement, but this view is mistaken if the mixture is sold under its old name, and the proportions