CONCRETE MIXTURES IN ALKALI SOILS

Field and Laboratory Tests Covering 39 Different Mixtures—Gunite, Powders and Paints to be Tested—Observation of Buildings and Experimental Walls—Paper Presented at Recent Annual Meeting of Engineering Institute's Saskatchewan Branch

By C. J. MACKENZIE
Professor of Civil Engineering, University of Saskatchewan

BRIEFLY the known facts concerning the effect of alkali waters on cement and concrete mixtures are as follows:—

1. By laboratory experiments it has been conclusively proved that magnesium and sodium sulphates, which are the predominating salts in our so-called alkali waters, will attack cement chemically; and under certain conditions of intimate mixture, completely disintegrate same. (See Montana Agricultural College Bulletin, No. 81.)

2. In laboratories it has also been proved that if a porous concrete be saturated and dried alternately, using a solution of soluble salts found in our alkali soils, that the process of crystallization will exert a force which will cause a splitting of the concrete. (Bureau of Standards Paper, No. 12.)

3. In practice, many cases have been observed where structures of concrete, as well as those of chemically inert and porous materials, such as brick, sandstone, etc., where exposed to alkali waters, have become disintegrated, suggesting that the mechanical force of crystallization is the action obtained.

4. Also numerous cases have been observed where the concrete exposed has become soft, pasty and bulged, with the total loss of its cementing value, suggesting a chemical action on the binding material.

5. In practice also we find structures of apparently the same grade of concrete exposed to the same conditions, one of which may be badly attacked with pitting and disintegration, while another appears unaffected.

According, therefore, to their personal experiences, there are those who hold that the action is entirely mechanical, due to the crystallization of the salts of the alkali water, and that, therefore, all required is a dense concrete. There are engineers and chemists who are attacking the problem from the purely chemical side. There are also a few engineers who hold that there is no effect from the alkali waters at all; that the trouble is entirely due to poor concrete, and the disintegration found in our western areas of alkali waters would have occurred similarly in the East and been accredited there to the action of the weather, etc., on a poorly fabricated concrete.

Seeking the Danger Zone

It follows, then, that, accepting the facts above stated, we may say that, while cement can be disintegrated by intimate action of alkali solutions in laboratories, and also that concrete of porous character can be disintegrated by the mechanical forces of crystallization under ideal laboratory conditions of saturating and drying, these ideal conditions will seldom, if ever, be found in practice, and consequently, deductions from laboratory experiments must be interpreted with a great deal of caution.

In practice the alkali water is not permitted the intimate contact with cement; nor do we find the rapid saturating and drying, and in addition, we have the extremely important problem of what effect the surface coating may have.

It would seem, then, that the most feasible method of attacking this problem is by actual field tests of concrete in the form of and under conditions found in practice. It is my opinion, and we have outlined our own experiments on this basis, that the most practicable way to approach the problem for the present is to subject, not a few mixtures to numerous varieties of water, but a number of widely different mixtures to conditions where disintegration is known to have taken place, and in this way, we may hope to get some idea as to which mixtures will stand the action of a typical alkali water and which will not. If we could establish even a danger zone, we would have accomplished something practical, and later the effect of other concentrations and the determination of just what chemical or mechanical action takes place when concrete fails could be undertaken.

The only published records of field tests of this nature being conducted at present, with which I am familiar, are those of the Bureau of Standards, Washington. Their experiments were initiated in an endeavor to determine the action of sea water on concrete, which we now know is of a similar nature to that of alkali action. Their first published report in 1912 covered an account of experiments conducted in the laboratory and a few field tests in the sea. This report proved only the theory of mechanical action by crystallization under laboratory conditions.

Bureau of Standards' Tests

The second report, published in 1917, is devoted to an account of the field tests made on various reclamation projects in the American West to determine the effect of alkali waters on concrete. The major part of the work covered by this report deals with cement pipe, but there are also the results of a year's experiments on block concrete. The results show nothing conclusive. The tile pipes were taken up and crushed, and from their installation in 1914 till 1916 it may be stated generally that all pipes showed increases in strength in alkali waters, although there were some cases of total failure of individual tiles, and even some of the tiles showing increase in strength were slightly pitted and attacked. It is very likely, however, that the future examinations will throw light on this subject. The only conclusions drawn are that richness of mixture alone will not prevent disintegration, and that poor tamping in several rich mixtures showed up much worse than lean mixtures in a well-made concrete.

The blocks were only in one year before inspection, and, with the exception of two cases, there was no effect noticed other than a slight pitting. The failure of two of the projects indicates that material and proper workmanship are of the greatest importance, but no conclusions of far-reaching effect are drawn at present.

The most encouraging aspect at present, to my mind, is not due to any of the results of direct experiment along this line, but to the great steps in the understanding and interpretation of concrete mixtures which have taken place within the past 18 months.

The question that concerns us chiefly as engineers to-day is, let me repeat, "Which mixtures, if any, will successfully withstand the action of the alkali waters as found in our western provinces?" This naturally demands that we must first have an intimate and complete knowledge of mixtures, and then investigate the action of alkali on a wide range of mixtures, and determine, if possible, which are suitable and which are unsuitable for our local conditions.

New Light on Design of Mixtures

I firmly believe that the principle reason we have obtained no definite conclusions up to the present is due to the fact that for the past years we have known practically nothing about the science of the design of concrete mixtures. How could we expect to obtain any definite information as to which mixtures would be suitable and which would not when we knew nothing more about the results of our mixtures than that they were mixed in the proportions of 1:2:4