quently in the country, especially in wooded sections. To detect the cause one had to know that certain elements, such as tannic acid, alkali salts, etc., foreign to most waters, do affect concrete.

Failure Due to Sand.—For an illustration of the effect of a poor quality of sand, consider the following case:

A cry of alarm came in from an engineer that the concrete in an important bridge abutment had been in place for over two weeks, and that in attempting to remove the forms it was found that the concrete was still so soft that it could be cut out with a knife. A brand of cement new to the work had been used, and the blame was, of course, placed on it. An examination showed that a footing for the abutment had been made of the brand of cement first used on the work and that, although ten days older, the concrete could easily be cut with a knife. The evidence eliminated the cement.

Examination of the sand showed it to be a well-graded, sharp sand, but a clue was furnished by some yellow-coated grains. The investigator had already had considerable experience with similar sand grains. A trip to the sand bank showed just what he expected to find. The bank had not been stripped of a top layer of yellow-coated sand, which gives a sand with which it is mixed a tendency to very materially delay the hardening of the concrete in which it is used. In time, usually several months, the concrete will harden and there is ultimately no harmful effect apparent. Lack of knowledge of this peculiar quality has caused an investigator of another piece of work to tear it out and rebuild.

Failure Due to Stone.—A very unusual condition existed in another case, but it emphasizes strongly the need of following clues. A concrete wall was apparently disintegrating due, as the engineers believed, to free lime in the cement. In various places on the face of this wall there appeared what can best be described as "blisters." By prying off these blisters there were produced small cones about 6 in. in diameter and 3 in. in height and in the apex of each could be seen a small, yellowish-white spot about the size of a small marble. The trouble was clearly not a case of free lime in the cement. One unusually large blister enabled the author to dig out from the apex a soft stone about 1½ in. in size. This stone did indicate the presence of free lime, and after a few weeks on the author's desk slaked into a powder. Examination of the stone composing the coarse aggregate soon brought out the following:

The crushed stone all came from the same quarry, but some came by a steam railroad and some by an electric railway. No concrete made by the former showed blisters. Concrete made from stone delivered by trolley did, but why? It seems that in the course of transportation by the trolley route, the stone was conveyed in waste dump-cars, across the grounds of the company owning the quarry and conducting a plant in which limestone is an essential raw material. These dump-cars had not been cleaned carefully, and to the good stone were added some small quantities of stone that had been through a chemical process and were on the verge of disintegration. In the concrete their expansive force blistered the face. By forbidding further deliveries by trolley the trouble was stopped.

These may be considered extraordinary cases, but it is the out-of-the-ordinary that makes trouble; if they were not the extraordinary they would probably have been guarded against. They are, at least, typical of points for which one must look if one would explain failures in concrete.

Failure Due to Workmanship.—Failures due to poor workmanship are seen so often that instead of citing particular cases it will be sufficient to briefly note some causes or results.

Failures from faulty design are shown in the mode of failure. The lack of proper proportioning may be clearly seen in a fractured surface; the grading of the aggregates is also similarly noted; and poor mixing and improperly placed concrete readily show themselves. All these are evident to an eye trained to know good or bad concrete. The failure to take care of laitance is made apparent by the seams that are bound to result from such a failure.

A concrete may be dense but not sound and hard, and "sounding" with a hammer will show up this characteristic. Too wet a mixture with fine sand or silt, or a crusher dust used as fine aggregate, may be a cause. It may be sound and hard and yet may be poor for certain uses because it is too porous. By scratching the face of unbroken concrete with a dull instrument, one may sometimes judge of proportions used and, in its early stage, can also judge somewhat as to the rate of hardening. A pocket glass in the field and a microscope in the laboratory help materially in determining the density, and in approximately the ratio of cement and fine aggregate to the coarse aggregates. The naked eye is all that is needed to observe concrete spoiled by sweepings of sawdust, shavings or blocks, or by waste carelessly dropped into a form. Lack of protection to fresh concrete from the sun or unusual heat may be noted by a "dried-out" and rapidly dusting surface, and from frost by a flaked and scaly surface.

Influence of External Forces.—Where concrete has apparently been good for a considerable period and has then begun to disintegrate, the reason for the failure must be sought in the character of the disintegration, whether it may be due to changes in the elements making up the concrete or to some external elements or forces that have entered into it. If due to an internal influence alone the fact will be noticed by the granular breaking up on the concrete. If due to an external force, such forces as sea water, alkali salts or electrolysis will be under suspicion as being responsible if the concrete has been under the influence of any of them. For many years all the failures of concrete were considered as being due to the formation of certain chemical relations; but as it is commonly acknowledged at present that an impermeable concrete will stand in sea water as well as elsewhere, although subjected frequently to more severe actions than other concrete, its failures are due frequently to the same causes as those of other concrete and therefore the same examinations should give the same results. Similarly, since electrolysis is considered as a cause for the breaking down of concrete, the liability of concrete being affected by its influence will depend upon whether the concrete comes under the influence of an electric current. If it does, then its influence needs to be examined. If it does not, then the examination should also follow the usual method.

The value of laboratory tests and analyses should not be overlooked. While perhaps not giving as definite information as a field inspection, they should be used to the fullest extent to help establish the strength or weakness of a reasonable theory for the cause of failure. Where time will permit, laboratory tests of concrete made of the aggregates under as nearly as possible the same conditions, will give results that should aid in determining the fault in the original. Test specimens so made and treated should give practically the same results, and when compared with test specimens made under ideal conditions or