FAILURE OF SEA-WATER CONCRETES.

THE failure of sea-water concrete has probably caused the concrete industry more arduous study, labor and anxiety than any other single trouble. There is yet considerable disagreement among authorities as to the causes of sea-water disintegration, but there seems to be quite general concurrence in the opinion that the formation of calcium sulphoaluminate by interaction between the sulphates of sea water and the aluminates of the cement, are in very large measure responsible. This salt, calcium sulphoaluminate, increases largely in bulk with crystallization, and if such deposition of crystals were to take place in the pores of concrete, disruption by physical action might reasonably be expected. If this disrupting action were repeated numberless times in each of the countless pores existent in the average concrete, serious if not total disintegration might be expected.

In Mr. N. C. Johnson's paper, read at the June convention of the American Society for Testing Materials, on the "Microstructure of Concretes," he states that if the formation of such an expansive crystallin material were pictured as taking place in the cement matrix of a concrete, there would have to be imagined a gradual straining of the confining material, until rupture took place. It is significant as to the correctness of such an hypothesis that in the cement matrix of all concretes so far examined which show outward signs of disintegration, interior evidences of such strain are found by microscopic study.

In babbitts and bronzes, incipient fracture from stress is evidenced by "shear planes," or "slip bands," where one portion of the material has flowed over the other. In Fig. 1, reproduced at 110 diameters, taken from pile caps, Staten Island Ferry Pier, New York Harbor, are shown similar "shear planes" in a sea-water concrete which is noticeably disintegrating. It will be observed that these shear planes are at right angles to the polish scratches on the specimen, so that the lack of identity cannot be questioned. Under visual examination, these show as iridescent bands, changing in color as the focus is changed, as if they went to a considerable depth and at an angle to the plane of the surface examined.

Mr. Johnson indicates that this is not an isolated case, but that it is one of the most characteristic of all the formations found in under-water concretes.

Fig. 2, at 110 diameters, shows a second sample taken from pile caps, Staten Island Ferry.

Fig. 3, at 110 diameters, shows a third sample taken from pile caps, Staten Island Ferry.

Fig. 4, at 110 diameters, is taken from Pennsylvania Railroad Co. ferry piers, Cedar Street and Hudson River, New York Harbor.

It is very evident that all are of the same general type and nature, and that they indicate a condition of incipient rupture which is not only indicative of tremendous internal strains on the concrete, but also of a possibly dangerous condition of incipient rupture along the planes of these strain bands.

With regard to the latter, it is at least reasonable to infer that any force of a potency capable of causing incipient fracture in the cement matrix would exhibit further manifestations. Assuming that these shear planes are also relief planes for tremendous confined crystallin pressures, an extension of the crystallizing substance into such relief planes might be looked for.

If these shear planes are actually relief planes for crystallin, expansive formations in the pores of concrete, it is reasonable to expect that these planes would find their origin in a pore or fissure. This is found to be true. It is not always possible to connect the shear plane definitely with any pore or fissure in the plane examined, but in others this can be readily done. In samples magnified to 130 diameters, the formation of these relief planes have been noted in radiants from a pore; and the hard crystallin filling, different in texture and color from the cement matrix, could be seen by visual examination almost filling the pore and putting out feelers, or wedges, into the radiating fissures.

Nor is it reasonable to expect these wedging tenacles to stop with the formation of a slight relief fissure. Such a fissure must necessarily be narrow and as well adapted as was the originating pore to draw up the salt-bearing solutions by capillarity. This would mean, by a repetition of the same actions of capillary attraction and of solution, concentration and crystallization, that

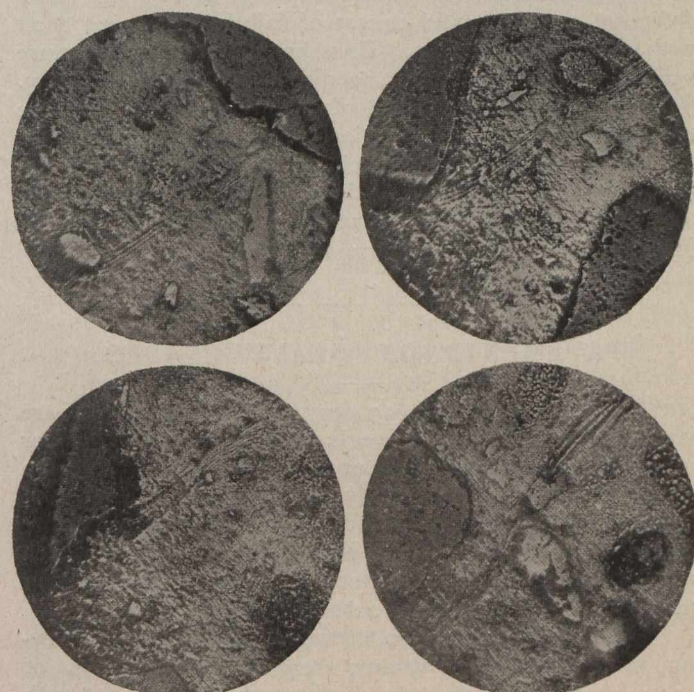

Fig. 1.—Examples of Shear Planes in Under-water Concrete (x110).

the formation of a crystallin intrusive feeler would follow in the relief fissure; and further, that this would grow so long as fresh supplies of solutions could be brought into it.

It has been found that these formations are not confined to salt-water disintegrations, and it must be inferred that compounds other than calcium sulphoaluminate are responsible for some disintegrations. Indeed, it would seem as if this line of reasoning might lead to an exclusion of sea water *per se* as the cause of disintegrations. The type of disintegration is cancerous in its nature, deriving its malignant substance through solution from the substance destroyed, just as cancer of the human issues has its sustenance directly from them. If this is true, the problem of making durable concrete for all services is essentially one of making concrete impervious.

Disintegrating actions of a like nature are exhibited in a number of concretes exposed to a wide variety of conditions of service. One of the most common are side-