calcium oxide content. The sand portion contains no soluble calcium compounds. Samples of soil along the line of this sewer had already been examined by a reputable firm of chemists. From a study of their report it is certain that the calcium compound could not have come from the soil or ground water. All this gives the clue to the origin and cause of the scale and encrustations.

"Now it can be easily demonstrated that as weak an acid as carbonic will decompose cement, provided enough fresh surface is exposed to the action of this acid. Hard, sound, neat cement pats can be dried and finely powdered. This powder can be exposed to the action of water containing carbonic acid. Eventually all the calcium oxide of the cement will go into solution as calcium bi-carbonate.

"All soil water contains organic acids, among which is carbonic acid. Thus if ground water should seep through the walls or joints of a sewer pipe the calcium oxide of the cement would gradually pass into solution and eventually the pipe would disintegrate.

"Just this thing is happening in all the concrete sewer pipe where the encrustations and scales are appearing. Ground water and sewer water gradually dissolves the cement and carries the calcium oxide into solution as calcium bi-carbonate. This water charged with the calcium bi-carbonate, and the scourings of the hydrated cement from the walls of the sewer, unite to form a normal calcium carbonate which binds the cement scourings, sand and other float in the sewer into a fairly hard scale.

"The cement pipe itself furnishes the binding medium whereby any sand and float is held in the sewer, i.e., the calcium bi-carbonate which is formed from the solution of the calcium oxide of the hydrated cement.

Can Obtain Non-Porosity

"In a large heavy wall sewer or a thick mass of concrete, even if quite porous, the dissolving action of ground water will take place, but this point should be noted: Disintegration will stop just as soon as the flow of ground water through the concrete is stopped. In any sewer pipe or a mass of concrete, this flow of water will depend strictly on the head of the water and of the porosity or void space of concrete. If the flow is rapid and the cement is dissolved and disintegrated before the silt and mud flowing along with the ground water plug up the pores, the concrete will go to pieces.

"This is the reason, we believe, why a porous drain tile will sometimes give good service when laid in clay soil, but a similar tile will go to pieces if laid in peat or sandy soil: The fine particles of clay plug up the pores of the concrete and keep the soil water away from the cement.

"Thus a thin walled cement pipe stands a far greater chance of being destroyed by ground waters than does a heavy walled pipe or a massive concrete wall. For this reason more trouble is to be expected with the small size pipe, say 30" and under, where the wall is thin.

"It is entirely possible to make a concrete pipe that will meet this requirement of non-porosity if enough cement is used, or if a water-proofing medium is used, and if extreme care is taken in curing. A mixture of one part of cement with two and one-half parts of carefully graded sand would be none too rich. With a 1 to 5 mix, or a 1 to 3 mix, even if most carefully mixed and placed, it is absolutely impossible to get a moisture-proof concrete.

"Even with a well-made, dense concrete, there is, in the light of recent investigations and reports, a strong presumption that percolating waters will enter the concrete mass and eventually cause deterioration. In our investigations of concrete railway tunnel linings, we noted numerous cracks and fine fissures in the mass of dense, sound concrete. These cracks and fissures can only be formed by natural expansion and contraction due to temperature changes and to alternate wetting and drying of the concrete mass. Such movement is inherent in the nature of a substance like concrete, made up as it is of a mixture of crystalline fixed aggregates bound together with a glue-like colloidal substance.

"Once these cracks and fissures are formed, percolating waters gain entry and disintegration is bound to take place to some extent, the damage depending entirely on the amount of surface exposed by the cracks and fissures. Ordinarily in massive concrete the cracks quickly become plugged up by infiltering silts and by the products of disintegration and little or no damage is done. However, if the cracks or fissures occur in thin walls such as of small size sewer pipe, the concrete is likely to fail before disintegration can be checked by the natural causes.

"In two tunnels that we examined these disintegration cracks had not become noticeable till the concrete was over ten years old. Cracks subject to ordinary sulphate-free water became plugged up and disintegration stopped. On the other hand, sulphate waters caused the cement of the concrete to soften and swell to seven times the original volume, this causing a progressive disintegration that gradually eats into the concrete mass.

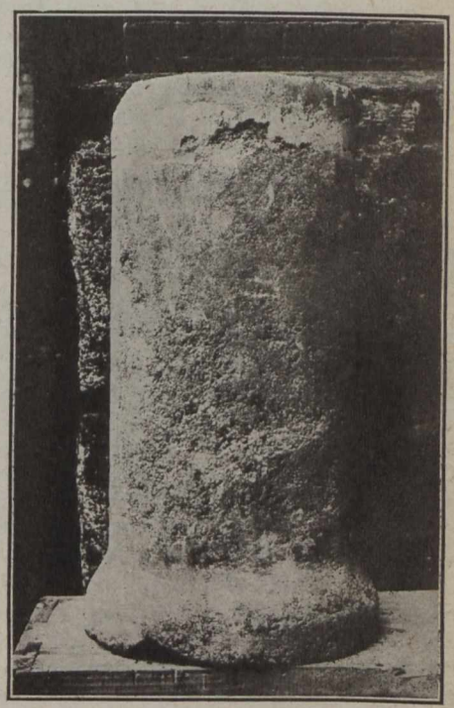

Fig. 3—Showing Disintegration on Outside of 12-inch Machine-Made Pipe Laid at Vancouver in 1913 and Taken Up in 1915

"Fig. 2 shows a magnified section of a piece of concrete taken from the wall of one of the sewer pipes in city yard—the pipe taken up from Glen Drive. This concrete, to the naked eye, appears very dense and of uniform texture, yet the microscope and magnifying glass show even more voids than shown in the print. This print makes it easy to see how readily ground water would pass through the walls of the pipe. This same sample from which the print was made gave an absorption of 8.8%, thus indicating a fairly dense concrete, as far as ordinary requirements go. In other words, a low absorption test is not always proof of density. A glazed surface may cause a low absorption test, while the interior of the pipe is full of voids. Once the glaze is scoured away or eaten off, the ground water has easy access to the body of the concrete.

Conclusions

"1.—A troublesome scale and encrustation is forming in the concrete sewers of Georgia Street and Glen Drive.