or 1: 3: 5, as the case might be, without any definite knowledge as to the final results of the concrete made?

A mix of, say, 1: 6, as is common with us, tells absolutely nothing about the finished concrete. The strength and character may vary several hundred per cent. on the same job, to say nothing of the variation in mixtures on different jobs using different materials and mixed by different men and different methods. (I make this statement advisedly as the result of actual tests made from concrete poured on various jobs.)

Mixing Concrete with Eyes Shut

For years we have been simply mixing concrete with our technical eyes shut. Certainly some engineers and some firms have been making concrete of the very best quality, while others, working to the same specifications and with the same materials, have been making concrete of an altogether different character. The thing that has troubled most of us is, I think, the fact that if we were given the ingredients in any case, including cement, sand, gravel and water, we could not calculate the strength of the finished product with any degree of assurance, although many men of mature judgment and wide experience could form a very good opinion.

Personally, I have done what was called sand and gravel analyses for several years. I have plotted the results on properly ruled paper along with Fuller's "ideal curve," handed the results along to clients, and even charged good money for it; but I tell you truthfully, the analysis never meant anything to me, and I am absolutely sure that it meant nothing to most of those to whom I sent it. All the time I prayed that someone would do something to clear up the meaning of gravel analyses.

During the years 1918-9 two independent experimenters accomplished what I consider to be the biggest step towards placing the mixing of concrete on a scientific basis that has been made for years. The names of the experimenters are Prof. Abrams, of the Lewis Institute, Chicago, and Capt. Edwards, until recently of the Department of Works of the city of Toronto.

At the risk of covering ground familiar to all, I wish to mention these methods, as we have mixed all our concrete for experimental purposes on these theories, and we have tested their value on various jobs in Saskatoon during the year and have found them very satisfactory and enlightening.

Great Advance in Scientific Proportioning

Prof. Abrams proved from the results of about 50,000 tests that the strength of concrete depends only on the ratio of water to cement for all ordinary workable mixtures. The aggregate functions only in determining how much water must be used to make the mix workable. He worked out a method of stating this property of aggregate in terms of a concrete number which he calls the "fineness modulus," and which is readily obtained from a screen analysis. Thus, if we observe the amount of water being used per bag of cement on any job, it is always a simple matter to calculate the strength of the resulting concrete. Or, if we are given an aggregate and we obtain its fineness modulus, we can calculcate how much water will be necessary for any mix and what the strength will be; or, if we wish to make concrete of a certain strength out of a certain aggregate, we can easily calculate the amount of cement required and the necessary water. By this method we have a means of comparing in actual figures of strength, and also of dollars and cents, the value of different aggregates.

Capt. Edwards, on the other hand, attacked the problem from an altogether different viewpoint, and concluded that, always providing the concrete mixture is of normal consistency or workability, the strength of concrete depends on the ratio of cement to the surface area of the aggregate. He worked out tables which, when applied to the mechanical analysis of an aggregate, will give the surface area per pound of the aggregate. And by this method also mixtures may be analyzed and designed as above.

While these two methods at first glance seem quite different, and even contradictory, they are almost identical in practical results, and have both been found to give satisfaction on actual work.

The scope of this paper does not permit of a thorough discussion of these methods, but if there are any engineers who are not familiar with these theories, I would strongly urge a serious study of them.

In outlining the experiments carried out in conjunction with the Committee on Concrete of the Saskatchewan Branch, Engineering Institute of Canada, it would be well to state that we recognized that the problem was a very large one, and that with the funds and facilities available at present, it would be better to confine our work to one particular district, and if results of any value are obtained, further grants might be secured for a complete survey of the province and test blocks placed in all the different localities where conditions of ground water, soil and available concrete aggregate differ.

We started with the premises as set forth in the opening paragraphs of this paper, and accordingly decided to undertake our work under three divisions: (a) Field tests; (b) observation of buildings under construction in areas known to be troublesome; (c) laboratory tests, both chemical and physical.

Field Tests

For the present we are devoting the major part of our time to the field tests, and to date we have placed in the ground specimens representing about 39 different concrete mixtures.

It was decided, in view of the fact that the pressing problem, in Saskatoon at least, is in connection with foundations and walls and not with tile, to make up our test blocks in cubes, with sides of 12 ins., thus approximating the conditions of walls. Each block is moulded in our laboratories, and a wrought-iron rod with anchor plate is inserted. The portion protruding forms a loop for handling, and has encircling it a brass identification disc.

The site for placing the test blocks was selected after a thorough investigation of the city, and is in the centre of the most troublesome area and is surrounded by buildings which have been affected.

Contiguous buildings were inspected to ascertain at what depth the most serious disintegration occurs, and we found that this was at a depth of 6 ft., where a small gravel seam, about 2 ins. in thickness, runs through the clay. This depth was used for our blocks.

The test blocks made to date are in six series, as follows:—

Series A—This series consists of thirteen blocks, ranging from a heavy, strong, well-graded, dense concrete to a very weak mixture of poor, pit-run gravel, so weak that it was impossible to even handle without knocking the corners off.

Blocks Nos. 1 to 5 were made with an aggregate of washed gravel and crushed stone. This aggregate is a good approximation of Fuller's curve. Its fineness modulus (according to Abram's method) is 5.5, and the surface area per gram (calculated by Capt. Edwards' tables) is 2.44. Mixtures by volume of 1: 2½, 1: 3.7, 1: 5, 1: 6.2 and 1: 7½ were used.

The ratio, volume of water to volume of cement, runs from 0.62 to 1.31, while the grams of cement per square inch of surface area of aggregate varies from 7.3 to 22.

Blocks Nos. 6 to 10 were mixed with a pit-run gravel as aggregate, the fineness modulus of which was 3.8; and the surface area per gr., 3.9 sq. ins.

The same mixes were used as in blocks Nos. 1 to 5, but the ratio, volume of water to volume of cement, varied from 0.82 to 2.4, and the grams of cement to surface area, from 11.7 to 35.1.

Blocks Nos. 28 to 30 were mixed with a pit-run gravel of a better grade, the fineness modulus being 4.8, and the surface area, 2.51 sq. ins. per gr.

The water-cement ratio varies from 0.81 to 1.59; the grams of cement per square inch of surface area, from 8.7