It is evident therefore that there are many differences of opinion on the proper proportioning of concrete, and a method has yet to be found whereby we can tell just how far we can cut the cement in a mixture with safety, since so many factors enter into the problem of making good concrete, such as the amount of cement used, the nature of the aggregate, the sand content of the aggregate, the amount of water, time of mixing and the placing of the concrete.

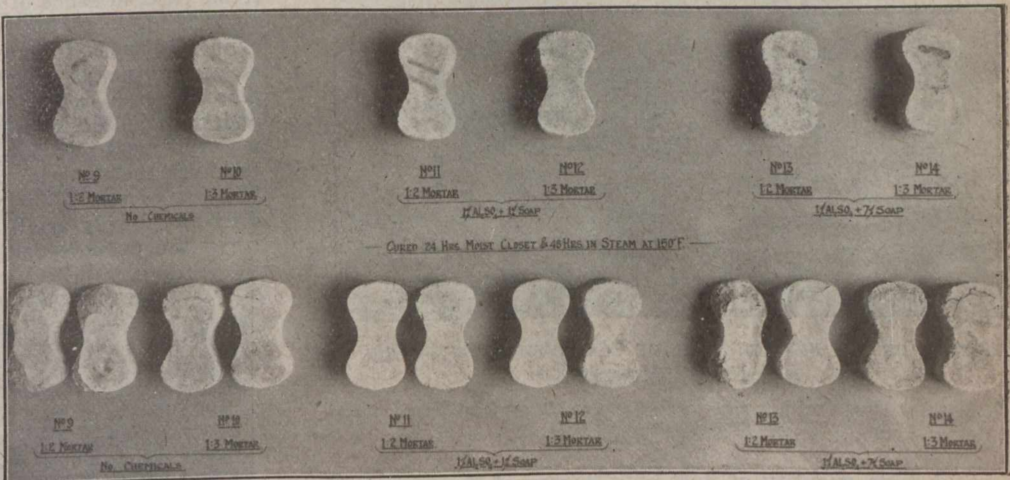
I have heard a great deal on concrete construction work about filling the voids in a concrete mixture and the idea seems prevalent amongst many engineers that this system of proportioning concrete is a good one. Below is an extract from circular No. 8 on the action of alkalies on hydraulic cements published by the Montana Agricultural College in 1911:—

"Much can be done towards the protection of concrete structures by the selection of good material and by proper care in proportioning the cement, sand and gravel. It is the work of the engineer and should not depend altogether on rules, but he should actually determine the amount of cement to fill the voids in the sand to be used."

In his chapter on proportioning concrete in Taylor and Thompson's treatise on concrete, p. 181, Mr. Fuller goes into the system of proportioning in some detail. He points out that the actual volume of voids in a given volume of stone may not, and usually does not, correspond to the quantity of sand required to fill those voids. The use of this method therefore leads to false conclusions, the reasons for this inaccuracy being chiefly because with most aggregates a portion of the particles of sand or fine screenings are too coarse to enter the voids of the coarsest material. The individual voids in a mass of broken stone or gravel are many of them so small that a large number of the particles of bank-run sand will not enter them but will get between the stones and increase the bulk of the mass.

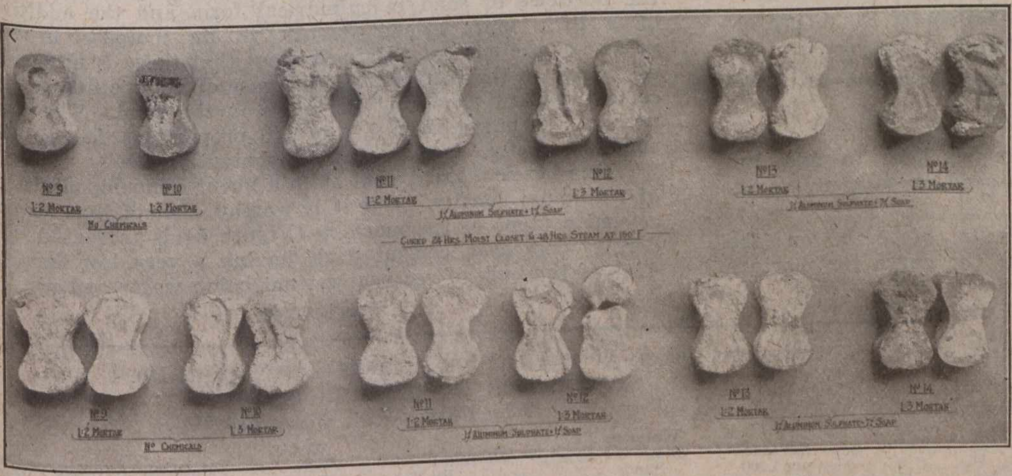
The determination of the proportion of cement to sand by void measurement is still more misleading and so inaccurate that he gives no consideration to it.

To further illustrate the absurdity of basing the amount of cement on the void filling theory, some density tests were made in our district laboratory, using sands of different grading and varying the cement content. The method of determining the absolute density of a mortar is shown in Figure 3, which is self-explanatory, and the usual method of determining the voids in a sand by mixing the sand with water and allowing it to settle is shown in Figure 4. The curve for theoretical density of mortar is obtained on the supposition that the space occupied by the water filling the voids in the sand can be replaced by cement paste without increasing the bulk of the sand. This supposition is of course erroneous, as will be evident from further tests, but it is to clearly illustrate this matter that this curve is drawn. According to this theory there is an exact and definite proportion of cement to sand at which the voids are filled with paste and the mortar will have its maximum density at this proportion. The addition of more cement paste above this proportion will only result in a reduction in density since cement paste itself has a low density. The addition of any less cement paste than this amount will also result in a reduction in density, as is shown in the curve, Figure 4. With the sand here used the voids should be exactly filled at a proportion of cement to sand 1:3.76. But if one attempts to mix cement paste with dry sand it will be found that the sand abstracts water from the paste and renders the mixture unworkable until sufficient water is added to wet



Action of Sulphate Solutions on Mortars Treated with Soap and Aluminum Sulphate

Briquettes immersed in solution for 8 months. Solution used, 10 per cent. sodium sulphate. Top row cured 24 hrs. in moist closet. Bottom row cured 24 hrs. in moist closet and 48 hrs. in steam at 150 degs. F. Top row shows no apparent action. Bottom row: No 9, disintegration at ends; Nos. 10 and 11, cracking at ends; No. 12, no apparent action; Nos. 13 and 14, cracking and disintegration at ends.



Action of Sulphate Solutions on Mortars Treated with Soap and Aluminum Sulphate

Briquettes immersed in solution for 8 months. Solution used, 10 per cent. magnesium sulphate. Top row cured 24 hrs. in moist closet. Bottom row cured 24 hrs. in moist closet and 48 hrs. in steam at 150 degs. F.

Top row: No. 9, no apparent action; No. 10, no apparent action on exterior, but section shows penetration of alkali; No. 11, distorted and disintegrated at ends and swollen; No. 12, swollen, distorted and cracked, one briquette disintegrated; No. 13, disintegrated at ends and swollen; No. 14, distorted and disintegrated at ends and swollen.

Bottom row: No. 9, cracked and disintegrated at ends and swollen; No. 10, swollen and badly cracked, distorted and disintegrated; No. 11, disintegrated at ends and swollen; No. 12, swollen, cracked, distorted and disintegrated; No. 13, swollen, cracked and distorted; No. 14, cracking and disintegrated at ends and swollen.