realizing the time and expense involved in such tests if properly carried out, it was decided to make some further studies of this method before recommending any action along this line.

The work of D. A. Abrams in his researches on concrete at the Lewis Institute, in Chicago, have established many important facts concerning concrete, and it was felt that the surface-area method, to be worthy of consideration, had to be in agreement with these facts. Consequently, the first study undertaken was to connect the work of Abrams with that of Edwards. The results obtained from this study show the work of these two investigators to be in entire agreement, Abrams' work throwing much light on Edwards' results and vice versa.

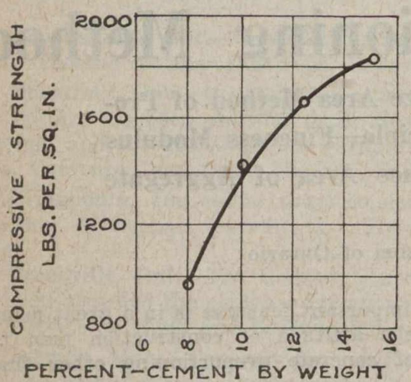

FIG. 4—RELATION OF COMPRESSIVE STRENGTH OF CONCRETE TO WEIGHT OF CEMENT (FULLER & THOMPSON)

The first step taken was to determine if any relationship existed between Abrams' fineness modulus and the surface area of a sand. This was done by calculating the fineness modulus and surface area of fifty representative sands, the mechanical analyses of which were assumed.

The fineness modulus obtained in this case was not exactly that of Abrams, since other sizes of sieves were in use, but the openings of these bore the same relationship to one another as did his and it was derived in a similar manner.

The analyses chosen gave a range of values exceeding 400%. When these were plotted in the form of a graph with surface area as ordinate and fineness modulus as abscissa, as in Fig. 1, it was found that the relation between these two are approximately that of a straight line.

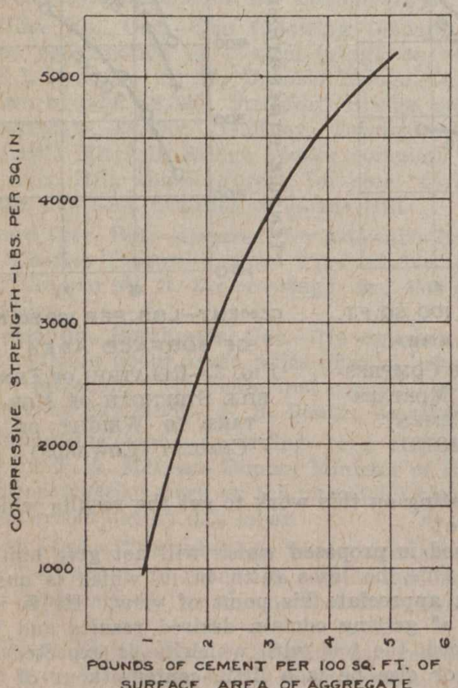

FIG. 5—VALUES OF *S* PLOTTED IN RELATION TO CEMENT PER UNIT OF SURFACE AREA

This was considered a very important point, for might it not be possible that the success which had been obtained with the fineness modulus in estimating the strength of and in proportioning concrete mixtures was due to this? It seems extremely likely, for so far as is known to the writer, no explanation of the reason for the success of the fineness modulus has ever been advanced accounting satisfactorily for its remarkable properties.

As a proof that the fineness modulus was not the same as the surface area of a material, but only a happy approximation of it, a formula for each was worked out as follows:—

Let us consider a set of six sieves, Nos. 1, 2, 3, 4, 5 and 6, the diameters of the openings of which decrease by one-half with each succeeding sieve in the set. It was found by actual experiment with a set of sieves having this ratio that the surface area per gram of material passing a certain sieve and retained on the next finer, was double that retained on that sieve but passing the next coarser. If, therefore, we take x as being the surface area per gram of the material lying between Nos. 1 and 2, $2x$ will be the surface area per gram of that between Nos. 2 and 3, $4x$ between that of Nos. 3 and 4, etc. Let a, b, c, d, and e be the percentages remaining between the different sieves as in Table I., then the fineness modulus is $(5a+4b+3c+2d+e)/100$, and the surface area per unit volume is $16ex+8dx+4cx+2bx+ax$. In other words the two have no mathematical relation, one to the other. Fig. 1 would lead one to suspect this, as but few of the points fall exactly on the line drawn.

TABLE 1.

Sieve Nos. Pass Ret'd on	Mechanical Analysis, % Remaining Between Sieves.	% Retained on Each Sieve.	Surface Area Per Unit of Volume.
1—2	a	a	ax
2—3	b	$a+b$	$2bx$
3—4	c	$a+b+c$	$4cx$
4—5	d	$a+b+c+d$	$8dx$
5—6	e	$a+b+c+d+e$	$16ex$
Total —	100		

Abrams has also shown that the strength of a concrete or mortar mixture depends upon the ratio of the volume of water to the volume of cement in that mixture. Strength is, therefore, a function of the water content of the mix. Upon what does the quantity of water depend, assuming that we use only sufficient to give a workable consistency?

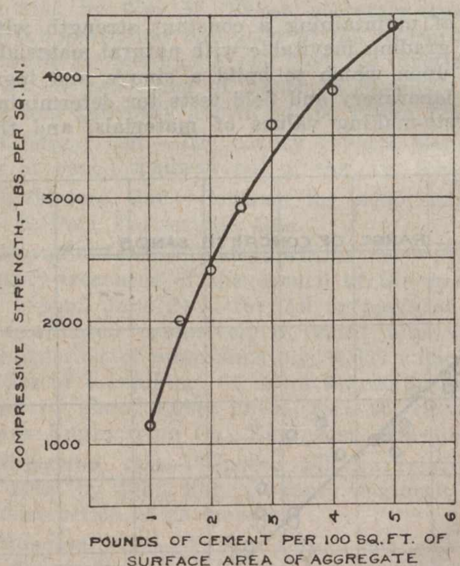

FIG. 6—RESULTS RECENTLY OBTAINED IN THE "HYDRO" LABORATORY

On consideration, we find that it is upon the quantity required to reduce the cement to a paste, plus the quantity necessary to wet the surfaces of the particles of aggregate.

The quantity required to wet the cement depends entirely upon the quantity of cement used, while the quantity required to wet the aggregate depends upon the total surface area of the particles forming the aggregate, and the latter is, in turn, dependent upon the sizes of the particles and the number of each size present in any given aggregate; or in other words, upon its grading or mechanical analysis.

If we assume the cement content and consistency to be the same, the conclusion then follows that the concrete which is made from the aggregate having the least surface area will require the least water in excess of that required to wet the cement, and will, consequently, be the strongest.

Strength depends upon the "water-cement" ratio and yet increases in strength may be obtained by increasing the cement content of a concrete. This can be explained by the fact that an additional quantity of cement in a concrete requires an additional quantity of water only sufficient to properly moisten the additional cement used, and therefore the total water does not increase in the same ratio as the total