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## PROPORTIONING MORTARS AND CONCRETES

IN proportioning mortars and concretes, does the strength depend only upon the cement-water ratio or upon the relation between the cement content and the surface area of the aggregate? That is the question which is now raised as a result of the experimental work done by Prof. Abrams, of Chicago, and by Capt. Llewellyn N. Edwards, of Toronto. On page 501 of our issue of June 6th, 1918, we reprinted an article by Duff A. Abrams, professor in charge of the Structural Materials Laboratory of the Lewis Institute, Chicago, in which he claimed that the strengths of mortars and concretes for given materials, made up and tested in a similar manner, depend upon nothing but the relation between the amount of water and the amount of cement in the mix. In his article Prof. Abrams says:—

"It is seen that for given concrete materials the strength depends upon one factor only—the ratio of water to cement. Equations which have been proposed for this purpose contain terms which take into account such factors as quantity of cement, proportions of fine and coarse aggregate, voids in an aggregate; but they have carefully omitted the only item which is of any importance, the water."

Prof. Abrams plots a curve showing compressive strengths in pounds per square inch in direct relation to the cement-water ratios. The equation of this curve he gives as  $S = A/B^x$ , where  $S$  is the compressive strength of the concrete and  $x = W/C$  ( $W$  being the volume of water and  $C$  the volume of cement),  $A$  and  $B$  being constants

whose values depend upon the quality of the cement, the age of the concrete and the curing conditions. For the conditions of the tests conducted by Prof. Abrams, he states that  $A = 14,000$  and  $B = 7$ .

"Other tests made in this laboratory," says Prof. Abrams, "have shown that the character of the aggregate makes little difference if it is clean and not structurally deficient. . . . In certain instances a 1:9 mix is as strong as a 1:2 mix, depending only on water content. The strength of the concrete responds to changes in water, regardless of the reason for these changes."

About the same week that Prof. Abrams announced the results of his tests, Capt. Edwards, supervising engineer of bridges of the Works Department of the City of Toronto, forwarded to the American Society for Testing Materials a paper describing a series of tests which he had made since November, 1917. The results of those tests do not altogether agree with the laws promulgated by Prof. Abrams, and the difference is of decided interest to users of mortars and concretes and will no doubt lead to much discussion, and probably to further investigation by Prof. Abrams, who is an earnest and indefatigable worker; he has accomplished research of unquestionable value and will be the first to desire to clear up any existing doubts as to the best method of proportioning.

Capt. Edwards agrees with Prof. Abrams that a plastic mix is essential and that excess water in an over-saturated mortar or concrete mix exerts a decidedly weakening effect upon the cement matrix by producing a change in the physical structure of the matrix which tends to destroy the cohesion existing between particles of cement and the adhesion existing between the cement and the aggregate; but as a result of his extensive tests, Capt. Edwards claims that the strength of mortar containing a given cement and sand but varying for the different mixes in the proportions of these ingredients, is directly proportional to the relation existing between the cement content and the surface area of the aggregate.

He assumes the use of enough water for a "normal," uniform consistency, and that there will be no excess of water, but he does not recognize that the compressive strength depends only upon the cement-water ratio. In Prof. Abrams' article there is no evidence that he takes into account the volumetric composition of the sand, to which Capt. Edwards attaches the maximum importance on account of the variable sand areas resulting from differences in the sizes of particles.

Capt. Edwards makes it clear in his paper that he fully realizes the importance of obtaining correct cement-water ratios, although not attaching the sole and exclusive importance to this item that does Prof. Abrams. In fact, Capt. Edwards has gone a step further than other investigators in showing the actual cause of weakening by the use of too much water. Prof. Abrams, Capt. Edwards and others have previously shown by many tests that an excess of water has a marked effect upon cement products, but nobody previously made it so clear as to the cause of this effect. Capt. Edwards' experiments show that the cause is a structural change in the cement matrix, which is the only material of the mix that has any cementing value.

Capt. Edwards claims that his method provides a means for a more thorough investigation of the functions of sand and stone aggregates and for more complete development of the true values of all component materials of mortars and concretes. The relations between the materials as established by Capt. Edwards will appeal more readily to the average engineer than will Prof.