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Practical Application of Surface Area Method

Of Proportioning Materials for Concrete, as Used by the Hydro-Electric Power Commission of Ontario—Economy of Different Aggregates Can Be Compared, as Workability and Strength, Formerly Variables, Are Now Reduced to Constants

By RODERICK B. YOUNG

Engineering Materials Laboratory, Hydro-Electric Power Commission of Ontario

CERTAIN fundamental considerations must be borne in mind in developing any method for proportioning concrete. Each element of a structure is designed to perform certain work, to accomplish which it must be constructed of materials having physical and mechanical properties at least equal to those assumed in the design, in order that the safety of that structure will not be endangered. Concrete is no exception, and therefore any method of proportioning, to be satisfactory, must be capable of producing concrete of the class required by the design of the structure in which it is being used.

This is not, however, the only requirement which has to be met in practical proportioning; other elements enter which must be taken into account. The materials vary from day to day, and these variations should be provided for with a minimum of interference with field operations and methods. Account must also be taken of the fact that the same consistency is not universally applicable, because different conditions, even on the same piece of work, may require concretes of different plasticity. The method must, therefore, permit of obtaining mixtures of any desired plasticity, and do this without sacrificing the quality of the concrete.

The attitude of the field engineer and contractor toward any method of proportioning to which he is not accustomed, must be borne in mind. The type of man found in construction work has, of necessity, a practical turn of mind, and is ordinarily impatient of involved methods. His business is to obtain results at a reasonable cost, and he is interested only in those methods which will do this with some certainty. He resents being hedged around with restrictions which hamper his operations, if reasons for these restrictions are not apparent. Therefore, any method to be applicable to field conditions must be simple in theory and easy of application. No other method, however complete and meritorious it may be, will get his support, and without his support it is impossible to get results.

Field Conditions Are Considered

In the method of proportioning developed by the Hydro-Electric Power Commission of Ontario, an attempt has been made to take these features into account. The method combines simplicity of theory, the requisite flexibility to fit field conditions, and a certainty of results. Its basic principles have been subjected to extensive experimental investigation and found sound.

In the finished concrete, strength is usually the prime consideration and is thus taken here. During construction another property is demanded of the concrete, and that is workability. The concrete must be sufficiently plastic and mobile to be handled and placed properly. Economy of materials and labor must also be considered. Other factors enter, but primarily the problem of proportioning concrete materials is to obtain in the most economical manner a workable mixture which will produce, in the specified time, concrete developing the required strength.

The binding material of a concrete is the product of the union of cement and water, which, before it can combine, is mixed to form a cement paste. This paste is used to coat the surfaces of the particles of aggregate, forming a film of cementitous material about each particle which binds the whole mass into one unit. The strength of this bond and therefore of the mass depends largely on the quality of this cement film, and this is, in turn, dependent on the concentration of the cement paste.

The quantity of paste which is required to bind any given mass of aggregate depends upon the quality of the paste, the mobility of the mixture, the combined surface areas of the particles of aggregate and, to some extent, on the character of their surfaces. However, with a given aggregate, if the quality of the cement paste and mobility of the mixture are fixed, the quantity of paste then becomes a function of the surface area of the aggregate.

Applicable to Workable Mixtures

The foregoing is closely analogous to paints and painting, for the service or protection given by a paint depends, generally speaking, upon its quality, while the quantity required for any particular job depends upon its "covering power," the area of the surface to be painted, and the character of that surface. This analogy has been found very useful in explaining our methods in the field.

It was first noted by Professor Abrams, as the result of his experiments at the Lewis Institute, that, within the range of workable concrete mixtures, the compressive strength of a concrete bears a very definite relation to a value which he has called the "water ratio" of the concrete. The "water ratio," or "water-cement ratio" as we prefer to call it, is the ratio between the volume of water and the volume of cement contained in the concrete mixture; or in other words, it is a measure of the concentration or quality of the cement paste.

Abrams has shown that for any given set of conditions—same aggregate, same cement, same age of concrete, etc.—this relationship is fixed within narrow limits, and that so long as the mixtures are practicable and workable, concretes having equal water-cement ratios will have approximately equal strengths. Our own experimental work further supports this conclusion. This, then, furnishes us with a means of obtaining concrete of specified quality, for if in any case the relationship between the desired compressive strength and the water-cement ratio is known for the set of conditions governing that case, it is only necessary to proportion the water and cement in the concrete mixture so as to give the necessary water-cement ratio and, if the mixture comes within the bounds of workable concretes, the required strength will result.

I have referred in my last paragraph to "workable" concrete mixtures; a concrete mixture must possess a certain degree of plasticity or mobility before it can be handled and placed. The second problem, therefore, in proportioning is to obtain in mixtures of the desired strength the necessary