be determined. Often only a few of the above mentioned factors may be given consideration due either to lack of testing equipment, or lack of appreciation of their necessity. As a result, some of the essential and important features which should be determined by test may be disregarded, and erroneous and misleading conclusions may be drawn from the few test data obtained. The most essential test data, which may in some cases explain why improper conclusions have been drawn, are often omitted as of no importance, and the conclusions may be so opposed to the well established results and experience of the field engineer that he is fully justified in his refusal to be governed by the results of the test data. The wide variation in tests results which have sometimes been obtained by groups of laboratories using similar materials in a specified manner by skilled operators, furnishes additional evidence that something is lacking in laboratory practice. A few of the laboratory methods which are sometimes responsible for such a condition of affairs are worthy of more detailed consideration.

Use of Dry Mixtures

Tests have repeatedly shown that the value of a sand for use in concrete cannot be determined by its use in a mortar, but that it should be employed with the same coarse aggregate which is to be used on the work. Sands which may be condemned as a result of tests in a mortar, may be satisfactory for use with a properly graded coarse aggregate. Any specifications for sands which limit the amount passing any given sieve are no doubt in many cases due to results obtained in mortar tests, and good concrete sands have been rejected because of such false conclusions based upon improper methods of test. To base judgment of a sand on tensile mortar tests is a still further step in the wrong direction and cannot be too strongly condemned. In some classes of work where a mortar is used the tension test may be proper, but the mortar test, either in tension or compression, is of little value in evaluating a sand for use in concrete.

The use of dry laboratory mixtures, unworkable under the usual field conditions, is another source of error sometimes encountered. This applies to tests of both mortars and concretes. A consistency which appears to mold well and produces good laboratory test specimens may be entirely impossible in the field, with the result that when the concrete is made on the job more water must be used to obtain a workable mix. A much weaker concrete than the laboratory tests would indicate is certain to result. It should be realized that in molding a laboratory test piece, considerable energy is expended in forming a small compact mass which is free from reinforcing steel and other obstructions, while in the field a small amount of energy is usually expended in placing a large volume of concrete which must flow in around a network of steel rods. Based on laboratory tests proportions of sand and gravel may be recommended which result in such a harsh, unworkable mixture that excessive amounts of mixing water, resulting in subsequent loss in strength, must be used for its proper placing. In case comparative tests are being made on materials from two sources of supply, the aggregate which may be judged inferior, based upon the comparatively dry laboratory consistency, may actually produce the stronger concrete in the field where a workable consistency must be used.

Use of Natural and Ottawa Sand

In laboratory tests the fact is sometimes overlooked that such a consistency as will result in maximum strength, or even approach such a value, will be entirely unworkable in the field. Some strength must be sacrificed to ease in handling and placing. Very often other properties are equally as important as compressive strength, yet most laboratory work is seemingly based upon the assumption that other properties increase proportionally within the increase in compressive strength. Experience in the field has indicated that this assumption is not true, and that concrete which must withstand water pressure, for instance, can well sacrifice strength for water tightness or impermeability.

Natural sands are often tested in comparison with standard Ottawa sand, using the quite dry consistency specified in laboratory tests of cement. Such so-called normal consistency mortars are too dry to be properly workable and should not be employed in tests of sand. The quantity of mixing water is insufficient to furnish a plastic, workable consistency, with the result that unnecessary errors are introduced both in mixing and molding which would otherwise be avoided. The attempt to bring the natural sands and the standard Ottawa sand to the same consistency will be made more nearly successful in case the wetter consistency is employed.

Usable Field Consistencies Should be Used

In construction work it is common practice to specify that a 1:2:4: concrete shall have a strength of 2,000 pounds per sqaure inch at 28 days, and with fairly good materials it is not difficult to obtain that strength in the laboratory, but the same mixture as used in the field has been known to have a strength 30 to 40% less than obtained in the laboratory, generally due to the necessity for using a greater quantity of mixing water. Lack of specification requirement and facilities for testing field concrete are responsible for such conditions not becoming better known. On one particular job, with given materials, the specified combination of 2 parts sand with 4 parts of gravel would not result in a concrete of proper and necessary workability when the quantity of mixing water was reduced sufficiently to result in a strength of 2,000 pounds at 28 days. Here the strict adherence to the specified proportion, together with the necessity for a certain minimum consistency needed for placing under the given conditions resulted in a concrete having considerably lower strength than was predicted from the laboratory results. Such a condition on the work could have been avoided had the laboratory tests given proper consideration to the field conditions.

It cannot be too strongly emphasized that tests of sands in mortars may bear little relation to their true values when used in combination with a coarse aggregate, and that usable field consistencies should be employed in the laboratory. Such practice will almost entirely do away with the use of such consistencies as are commonly associated with the use of normal consistency Ottawa sand mortars.

Consistency Should be Measured

Probably the one greatest cause for the divergence between laboratory results and field practice is the lack of some method for properly measuring and expressing the consistency, workability, or flowability of a mortar or concrete mixture. While the quantity of water used in any concrete or mortar mixture is easily determined in the laboratory, when working with dry materials there is no method in common use for properly measuring the consistencies so obtained. We are familiar with the terms "dry," "plastic," "mushy," "fluid," etc., but these expressions are inexact and do not mean quite the same to any two operators, and from day to day, especially when working with aggregates varying widely in granular composition, are not used in the same way by the same operator. Although it is well understood that change in the water content causes greater change strength than variation of any other single factor, we lack any method of test which will definitely and accurately classify any consistency so that it can be duplicated by other operators, or even by the same operator. In other words, one of the necessary and fundamental methods for the testing of concrete aggregates is lacking, and as a substitute we judge by "eye" and "feel." Throughout the test all materials may have been followed, yet the most important factor, the consistency, has merely been crudely estimated. Although we recognize that concretes must be of the same consistency to be comparable, we compare strength results obtained with materials which require wide differences in the quantity of mixing water to give the same apparent consistency.

A study of the results of comparative tests made in this manner indicates that the judgment of the operator is a very poor substitute for a method of measuring the consistency of a mixture. In a series of carefully made tests