The water cement ratio as in the other example = 12 35 lbs water per 28 9 lbs of cement = 4 83 gal per bag of cement

The concrete will require 28 9 lbs cement per 1.75 cu. ft of concrete $= \frac{27}{1\ 75} \times 28.9 = 446$ lb per cu. yd = 1.19 bbl. per cu yd

It is possible that this mix would be found too dry for good workability, in which case, a redesign for higher relative water content would be necessary

TESTS ON FINISHED CONCRETE

F C LANG
Minnesota Highway Department

Portland cement concrete is a manufactured product. The materials used are Portland cement, water, and mineral aggregates In general, these materials are combined to form concrete on the job For this reason the manufacture of concrete presents problems in quality control not encountered in the majority of manufacturing processes This local manufacture results in the use of a large number of relatively small portable manufacturing plants, and, for the most part, unskilled local labor is employed The production varies at any one location from a few cubic yards for monolithic culverts to thousands of cubic yards for pavements The manufacturing process should be such that concrete of the desired properties is obtained with the most economical use of the available materials. Tests of the concrete are necessary to determine its properties

When large quantities of concrete are required, it may be economical to apply the latest developed principles, using laboratories and employing very rigid control for every operation This would assure obtaining uniform quality of concrete at lowest cost for materials used. For such concrete a small factor of safety could be used in design On the other hand, for small yardages it may be more economical to spend less for field control and more for materials This would result in less uniform concrete and necessitate the use of a larger factor of safety

Accordingly, we may divide the concrete to be tested into two classes:

1 Concrete produced in large quantities, scientifically designed as to mix and rigidly controlled in the field Concrete produced under these conditions will be uniform in its properties

2 Concrete produced in small quantities, using arbitrary mixes, with little or no control Such concrete is likely to be variable in its properties

In highway work, concrete is principally used in two ways: For pavements where the design is based on flexural strength, and for bridges where the design is based on compressive strength In pavement design the working stress is usually much closer to the ultimate than is that used in the design of bridges

In all cases, tests on the finished concrete should be made. The purpose of making these tests is two-fold:

1 To ascertain the strength of the concrete at any particular time This is of value in knowing when to open pavements to traffic or to remove supports in bridge construction
2 To determine the ultimate quality and uniformity of the concrete This is of value in ascertaining whether the manufacturing process has been properly carried out, and should be a final proof of the intelligent control of materials and manufacture

At present the three following methods of determining the quality of finished concrete are generally used

1 The compression test made in the laboratory on specimens moulded and partially cured in the field The specimens are usually six by twelve (6 x 12) inch cylinders and are tested at seven or twenty-eight days
2 The compression test made in the laboratory on specimens drilled from finished concrete at various ages, but usually more than twenty-eight days after construction
3 The transverse test made in the field on specimens moulded and cured in the field

It is essential in any of the three methods that the specimens be very carefully tested When specimens are moulded in the field, very definite instructions should be given to specially trained field men, stating exactly when and how to make and cure the specimens. The importance of uniform and standard manipulation in the making and testing of concrete specimens cannot be over-emphasized The results of tests are only indications of the quality of the concrete when the variables of making, curing, and testing are reduced to a minimum.

Standard methods of making compression tests on concrete (Serial Designation C 39-27), of making and storing specimens of concrete in the field (Serial Designation C 31-27), and of securing specimens of hardened concrete from the structure (Serial Designation C 42-27) are published by the American Society for Testing Materials There is no such standard for the transverse test

The compression tests on moulded specimens has been by far the most extensively used, and the compressive strength at twenty-eight days is in general use as a criterion of quality Good concrete will show a high result in either a compressive or transverse test, but there is no constant relationship[1] Hence, it is preferable to make tests that will determine directly the property or properties desired The committee considers that the compression test on moulded specimens is of most value in highway work for bridges and culverts where the concrete is designed according to its compressive strength The standard for comparison should be determined at the laboratory, using the same material and water cement ratio that would be used in the field If tests on specimens made in the field indicate that the concrete is not coming up to the standard established in the laboratory, then a diligent search should be made for the reason Examination should be made of the method of making and curing specimens, of the quality and quantity of the materials, including the water, and of the concrete-mixing operation The importance of the correct design and operation of the mixer has not received sufficient attention

Except for very special conditions, all specimens should be cured in a standard manner, with close control of humidity and temperature On account of the difference in mass, it is usually impossible to cure a small specimen exactly the same as the concrete in the structure It is, therefore, not possible to say that the specimen at any age exactly represents the concrete in the structure Nevertheless, as an aid in determining when to remove forms, especially during cold weather, compression specimens may be cured as nearly as possible under the same conditions as the structure Such specimens, however, should not be considered when determining the final quality of the concrete

The compression test made in the laboratory on specimens drilled from finished concrete is of considerable value in testing the concrete in pavements, and has been extensively used for this purpose. It has

[1] Flexural Strength of Concrete Structural Materials Research Laboratory Bulletin No 11

What are the Most Significant Tests for Concrete? A T Goldbeck Proceedings of American Concrete Institute Vol XXII Page 388

Transverse Tests as a Criterion of the Quality of Concrete H S Mattimore Symposium on Field Control of the Quality of Concrete A S T M 1927 a very good moral effect on the construction men The measurement of hole and core gives a good check on thickness of slab The compression test on the core should show the quality of the concrete The results of this test as reported show a wide variation in compressive strength[2] Such results have been cited as evidence of the fact that uniform quality of concrete is not being obtained It is possible that part of this non-uniformity may be accounted for by the relative diameter of the core to the maximum size of aggregate and to the method of testing The committee is of the opinion that very definite instructions should be prepared, giving detailed instructions for taking cores and testing them

Inasmuch as concrete pavements are now designed according to the flexural strength of plain concrete, the transverse test should be used in determining the quality of the concrete It should be used for designing the mix and for field control The transverse test can be made on inexpensive equipment in the field This takes the laboratory into the field and develops a keener interest for good concrete among construction engineers and contractors It provides a method of measuring quality on the job, heretofore the only job measurement has been quantity.

The field transverse test can be used to ascertain the percentage of designed strength attained at any particular time, or with proper control over curing conditions the ultimate quality of the concrete can also be measured by this test By means of this field test pavements can be opened to traffic as soon as the required strength is obtained The prevailing practice as expressed in specifications has been to keep the pavement closed a certain period of time, such as three weeks Inasmuch as it is well known that the strength of concrete depends to a great extent upon temperature and moisture, such a requirement seems entirely illogical The traveling public should not be forced over long and tedious detours when it can be definitely known if the pavement has obtained sufficient strength A certain classification of traffic permitted on pavement according to wheel-loads and modulus of rupture of concrete in test specimens might be made. One state is doing this

The field transverse test has so many advantages that it is becoming quite extensively used Unfortunately, however, no technical body has standardized the test At present there are about as many types of

[2] Public Roads Vol 5 No 3 Page 27
Engineering and Contracting Vol 54 Page 449

machines as there are states using them In order to obtain information, the committee sent a questionnaire to fifteen states Replies were received from twelve They are summarized as follows:

In answer to question No 1—Are you using a field transverse testing machine for determining strength or quality of concrete?

Seven states answered "Yes"

Five states are making arrangements to do so

In answer to question No 2—If so, please enclose such details and photographs of your type of machine as you have available—

Photographs were received from several

In answer to question No 3—Have you made comparative tests showing relation between modulus of rupture as determined by your field machine and any other transverse machines, or comparison with compressive strength?

Four states submitted data showing results of comparison of transverse and compressive strength with no definite relation. Practically no results were received on comparison of the field transverse machine with the standard transverse beam tests

In answer to question No 4—Please send a copy of your instructions for making and curing of beams, also state size of beams—

Four states had fairly definite instructions for casting, curing, and testing beams They are not the same The other states had no definite instructions prepared There was considerable variation in the size of the beams

Two states specified 6 x 6 x 30″

One state specified 6 x 6 x 36″.

Two states specified 6 x 8 x 40″.

One state specified 6 x 6 x 32″.

Two states specified 6 x 8 x 30″

One state specified 7 x 10 x 38″

In answer to question No 5—What is your strength requirement for opening concrete pavement?—

Two states had a minimum modulus of rupture requirement of 350

One state had a minimum modulus of rupture requirement of 400

Two states had a minimum modulus of rupture requirement of 450

Two states had a minimum modulus of rupture requirement of 500

One state had a minimum modulus of rupture requirement of 600

One state had a minimum modulus of rupture requirement of 350 to 450, depending on amount of heavy traffic

Pennsylvania has a chart for opening pavement according to wheel loads and edge thickness

Some of the states had not put a strength requirement for opening concrete pavement into effect, but were expecting to

Replies to the questionnaire show conclusively that there are variations in type of machine, in size of specimen, and in interpretation of results Replies also show non-uniform practice for casting and curing the specimens With all these variations it is scarcely to be hoped that the modulus of rupture as obtained by one state could be compared with that obtained in some other states The committee considers that this method of field determination of strength of concrete is very valuable, but that the tests and equipment should be sufficiently standardized so that the results may be compared, and will truly represent the factor used in design of the pavement.

CURING CONCRETE PAVEMENTS

F H JACKSON AND J T PAULS[1]
United States Bureau of Public Roads

Within the past few years a number of methods for curing concrete pavements, designed to take the place of the conventional water-curing process, have been introduced and actively promoted in this country This has created a somewhat confusing situation, as regards this important feature of the construction process, which should be clarified as soon as possible The all-inclusive claims which are made for each of these special curing agents, together with the more or less conflicting reports as to the results so far secured, have yielded but little definite data upon which the specification writer can depend with any degree of assurance

From a strictly economic point of view, almost all of the proposed methods of curing are preferable to the old style water-curing process, largely because of ease of application and the fact that no attention is required subsequent to application. There is probably no feature of the construction process so difficult to control as curing by means of water, due to the difficulty of maintaining an adequate supply over several days' run of pavement Then, too, adequate supervision of the sprinkling operation is extremely difficult, which makes this feature an endless source of contention between the engineer and the contractor It is evident, therefore, that there is a real field for a method or methods of curing which will be as economical, more easily controlled,

[1] This is a joint report by the committees on Materials and Design