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A STUDY OF A METHOD TO DETERMINE THE CONSTITUENTS OF FRESH CONCRETE

Thesis for the Degree of B. S.
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Walter Ralph Bammel
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THESIS

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THE STUDY OF A METHOD TO DETERMINE THE CONSTITUENTS OF FRESH CONCRETE

A Thesis Submitted to

The Faculty of

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of

Agriculture and Applied Science

by

Walter Ralph Bammel

Candidate for the Degree of

Bachelor of Science

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THESIS

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DEDICATION

To Asst. Prof. Lee J. Rothgery of the Civil Engineering Department, from whom I have gained a wealth of knowlege in the field of concrete, I dedicate this Thesis.

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INTRODUCTION

At the present time it is believed that the quality of a given concrete can be definitely established if the actual constituents of the mixture as finally placed are known. It has been general practice to determine the quality of concrete by compression tests on a cylinder poured at the time the mixture is placed in the forms. This method has a disadvantage in regard to time, an element the people of today are greatly concerned with.

The need for a test to analyze the fresh concrete mix as to its water / cement ratio and proportions of cement, fine and coarse aggregate can at once be recognized. The "ready mixed" concrete industry has created a need for the ability to analyze concrete quickly. Strength specifications based upon w/c relationships determined from previous tests make it desirable to control the strength by maintaining these relationships or to predict the strength if they may be determined by test. Field control and a check on the contractor add to the needs for a test of this sort.

This paper is not written with the intent to offer a new a new method for the analysis of fresh concrete, but is a study of the Dunagan Test for the field determination of the constituents of fresh concrete. Therefore, the purpose of this paper might be stated as follows:

(a) To present a detailed picture of the Dunagan method.

(b) To present the actual results of a large number of tests conducted on batches of fresh concrete of different consistencies.

(c) To analyze the results of these tests as to the accuracy of this pattticular method.

The test outlined in this paper makes the fullest use of knowlege as to what constitutes concrete of a given quality; it attacks the problem in a direct manner with the maximum economy of time and expence. The solution offered is to take samples of the fresh concrete from the structure at any point and determine the amounts of its significant constituents, namely the water, cement, and fine and coarse aggregate. The concrete can be tested at any time before it has definitely hardened. Since on any given job it is not necessary to check up on the material more than every two hours, any competant inspector can handle this test along with his other duties.

The principle used throughout is the old Archimedian principle of water displacement, eliminating all necessity of the drying of any of the constituents. The displacements of the materials are measured from their boyancy in water. One feature of the test that is of particular advantage is that, except for the inital weighing in air which should be done as soon as the sample is selected, the test can be deferred to a any time within the setting period for after the initial weighing of the sample in air any water lost is of no consequence since "water in water weighs nothing."

The Dunagan method is far from being the only method of determining the constituents of fresh concrete. Solutions by other methods have been offered by G.S. Griesenauer, R.L. Bertin, and W.I. Freel. The three main procedures attempt to determind the amounts of the ingredients from their displacement rather than by drying them after the cement has been removed by washing through a No. 100 sieve. The first method, the one used by Dunagan, determines the displacement from the boyancy of the materials; the second determines the displacement by means of the volume of water displaced in a cylinder using the same principle as that used in the A.S.T.M. flasks for specific gravity determinations; the third method obtains the displacement by means of weighing a cylinder container used as a pycrometer.

Reasons why the Dunagan method seems to be the most practical to work with are as follows:

(1) Neither of the other methods were flexible and they required special apparatus not suited for use in other tests. However, in the Dunagan method the specific gravity, free moisture and absorption tests were unified causing the control tests to become a series of connected tests rather than isolated determinations.

(2) This method permits deferring the test. In using a cylinder as in the second method, the water in the sample must be retained and its displacement noted. Any loss

through evaproation makes the test inaccurate.

(3) The Dunagan method combines the advantages of all three methods. That is, aggregates can be easily recovered and surface dried as a check, this being a necessity in the second method. This is also a feature of the third method. The size of the sample is not limited. A large sample could be tested in sections so that the apparatus might be small enough for portable field operation. Then too, the boyancy principle permits greater accuracy in weighing with less expensive equipment.

The accuracy required as test for the analysis of fresh concrete should also be looked into.

In proportioning a batch a degree of accuracy must be maintained consistent with the accuracy with which the analysis is to check the batch. For example: if it is expected to check within $\frac{1}{4}$ gal of water per bag of cement the free moisture or absorption of the aggregates should be controlled within 0.2%.

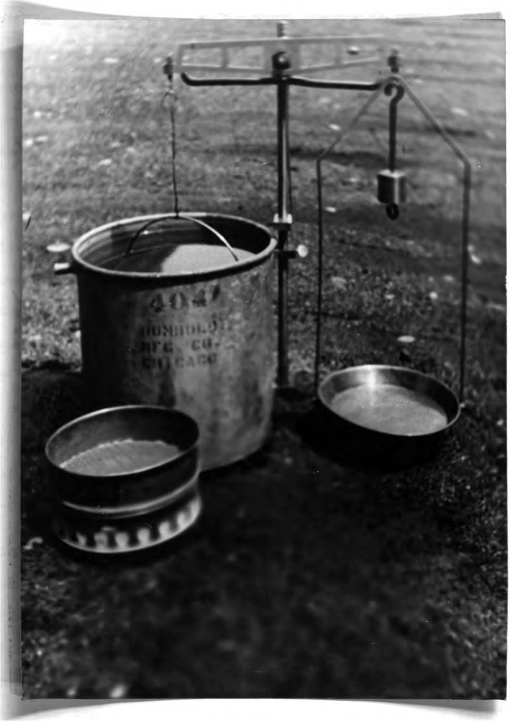
In sampling; samples should be taken so that they are truly representative of the batch. Of course the series of tests conducted for this paper were to analyze a total batch assuming that if the results met with the required accuracy for this case, the results would be equally accurate in analyzing a portion of a batch if a representative sample were chosen.

The analysis for the w/c ratio is the ultimate criterion of accuracy. The value of determining the amount of cement depends upon the relative amount of water so that it may be considered with the water as a ratio. With a given unit volume of typical concrete the water is a relatively small percentage by weight. In a one bag mix containing the proportions of 1 - $2\frac{1}{2}$ - 4 by weight the total materials are about 760 lb.; of this 56 lb. is water, or but 7.3% by weight of the total batch. Since it is desirable that the water be controlled within $\frac{1}{4}$ gal per bag of cement it is necessary that the accuracy required is 2 lb. in 760 or 1/380.

If absorption and free moisture tests are not preformed more colsely than within 0.2% the analysis of the concrete should not be required to check closer than within 0.2 gal per bag of cement.

To summarize, if the tests are carried out with the desited accuracy they not only furnish the w/c ratio, proportions of cement, and fine and coarse aggregate, but will also furnish a method of checking the efficiency of mixing and placing operations.

Apparatus set for weighings in air



Apparatus set for weighings immersed

Plus nested sives

PROCEDURE

The equipment for this test was obtained from the Michigan State Highway Department, whom I wish to thank for their coutrtesy and generosity. The apparatus was intact with the exception of the rider which had to be calculated. Although the beam was graduated in grams and tenths of grams, I wished to make a rider that would convert that scale to tenths and hundredths of a gram. Therefore, the apparatus was set up for weighing in air, and a 0.5 gm weight was placed in the right hand weighing pan. The scale was balanced by means of the small adjustment screw weight. Then this 0.5 gm weight was taken off the pan and a piece of wire was placed over the zero graduation on the beam and the material was filed off the wire until the scale again balanced. Now thescale should be ready for weighing. To test it I placed a 1.0 gm weight in the right hand weighing pan and the rider over the 1.0 gm graduation. The scale balanced proving the accuracy of the riders weight.

Before the actual tests to determine theconstituents of fresh concrete can be run it is necessary to determine the specific gravity of the cement and the fine and coarse aggregates. It is also necessary to find the percent cement retained on the No. 100 sieve and the percent of fine aggregate passing the same. These tests were conducted in the following manner.

Tests for Specific Gravity and Absorption of Coarse Aggregate

Scope: This method of test is intended for use in making determinations of apparent specific gravity and absorption (after 24 hours in water at room temperature) of coarse aggregate. It is the method specified by the American Society for Testing Materials.

The apparatus used was that which was used for the whole series of tests.

Procedure: Approximately 5 Kg. of the aggregate was selected from the sample to be tested, rejecting all material that passed a No. 4 sieve.

The sample was immersed in water at room temperature. It was them thoroughly agitated to remove dust or other coatings from thw surfaces of the particles and allowed to absorb water for 24 hours. It was then removed from the water and rolled in a large absorbent cloth until all visable films of water are removed. However, the surfaces of the particles still appeared to be damp. Care must be taken to avoid evaporation during the operation of surface drying.

The weight of the sample in the saturated surface-dry condition was then obtained. This and all subsequien weights were obtained to the nearest 0.5 gm. After weighing, the saturated surface-dry sample was then placed immediately in the copper bucket and its weight in water determined.

The sample was then dried to constant **weight** at a temperature of 100 to 110 degrees Centigrade, cooled to room temperature and wieghed.

A is the weight in grams of oven-dry sample in air.

B is the weight in grams of saturated surface dry sample in air.

C is the weight in grams of saturated sample in water.

$$\text{Apparent Specific Gravity} = \frac{A}{A-C}$$

$$\text{Percentage of Absorption} = \frac{(B-A)100}{A}$$

Sample Computation:

Trial I.

A = 706.45

B = 717.45

C = 448.04

$$\text{Specific Gravity} = \frac{706.45}{706.45-448.04}$$

$$= 2.73$$

$$\text{Absorption} = \frac{717.45-706.45}{706.45}$$

$$= 1.56$$

Results of Tests:

	A	B	C	Sp. Gr.	Absorption
Test I	706.45	717.45	448.04	2.73	1.56
Test II	946.91	958.40	601.22	2.74	1.21
Test III	898.30	907.15	572.04	2.75	0.985
Average Results				2.74	1.25 %

Tests for Absorption of Fine Aggregate

Scope: The purpose of this test is to determine the amount of water absorbed by the fine aggregate.

Apparatus is the same as was used throoughout the whole series of tests.

Procedure: A volume of sand was selected from the bin and placed in a pail of water to stand until saturated. The length of time was taken to be 24 hours.

After saturation, the sample was removed from the pail, spread on a flat surface exposed to the air, and stirred till the surface moisture disappeared. The fine aggregate was dried until it became free flowing. In order to gage more accurately the end point, the sample was placed in a dry quabt glass jar and the sand shaken against the sides of the jar. When the grains just tended to adhere to the sides of the jar, a test was made. Three tests were made in succession to obtain the absorption value.

S is the weight of the saturated surface-dry sample.

D is the weight of the same sample dried to a constant weight,

$$\text{Percent Absorption} = \frac{S-D}{D}$$

Sample Computation:

Test I $\quad S = 528.06$ $\quad D = 521.03$

Percent Absorption

$$\frac{S-D}{D} = \frac{528.06-521.03}{521.03} = 1.35$$

Results of Tests:

	D	S	Percent Absorption
Test I	521.03	528.06	1.35
Test II	735.64	743.53	1.05
Test III	628.57	634.34	0.905
Average Result			1.12

Tests for Specific Gravity of Fine Aggregate

Scope: This test is used to determine the Specific Gravity of fine aggregate. The principle back of this test is that the specific gravity is equal to the fine aggregate's dry weight divided by its loss of weight in water.

Procedure: A sample of fine aggregate was taken from the bin, saturated, and then surface dried.

This sample was placed in the copper pail and its weight immersed determined. The weight of the sample dried to a constant weight was then found.

A is the weight in grams of the oven dried sample in air.

B is the weight in grams of the saturated sample immersed in water.

$$\text{Specific Gravity} = \frac{A}{A-B}$$

Sample Computation:

Test I $A = 1130.69$ $B = 708.61$

$$\text{Specific Gravity} = \frac{1130.69}{1130.69-708.61} = 2.68$$

Results of Tests:

	A	B	Specific Gravity
Test I	1130.69	708.61	2.68
Test II	1181.34	741.60	2.69
Test III	1021.94	640.58	2.68
Average Results			2.68

Tests for Specific Gravity of Cement

Scope: This test is used to determine the specific gravity of the cement used, Portland cement.

The method of the American Society of Testing Materials was not used because it is believed that there should be a direct relationship between the test for specific gravity and the test to determine the constituents of fresh concrete. Therefore the same apparatus was used in this test as in the previous ones.

Procedure: A sample of the cement was taken and its weight determined. This same sample was then placed in the copper pail and the weight immersed determined.

A is the weight of the cement from the bin.

B is the weight of the cement immersed.

$$\text{Specific Gravity} = \frac{A}{A-B}$$

Sample Computation:

Test I $A = 537.37$ $B = 364.20$

$$\text{Specific Gravity} = \frac{537.37}{537.37-364.20} = 3.10$$

Results of Tests:

	A	B	Specific Gravity
Test I	537.37	364.20	3.10
Test II	455.06	307.33	3.08
Test III	452.24	303.14	3.04
Average Results			3.10 ?

Tests for Percent of Cement Retained and

Percent of Fine Aggregate passing No. 100 Sieve

Scope: The purpose of these tests are to determine the percent of cement retained on a No. 100 sieve and the percent of fine aggregate passing the same.

Normally not all cement passes through the No. 100 sieve and some of the sand passes, but in both cases the amounts are quite small and often offset each other.

Procedure for Cement: A sample ot cement was taken from the bin and weighed. This sample was then placed in the #100 sieve and washed for a time period of five minutes. The material remaining on the sieve was dried and weighed.

A is the weight of sample of cement.

B is the weight of dry material retained.

$$\text{Percent retained} = \frac{B(100)}{A}$$

Sample Computation:

Test I $A = 364.20$ $B = 8.57$

$$\text{Percent Retained} = \frac{8.57(100)}{364.20} = 2.36\ \%$$

Results of Tests:

	A	B	Cement retained
Test I	364.20	8.57	2.36%
Test II	307.33	4.14	1.35%
Test III	303.14	3.33	1.11%
Average Results			1.61%

Procedure for Fine Aggregate: A sample of the fine aggregate was taken from the bin and its weight obtained. This sample was placed on the #100 sieve and washed for a period of five minutes. After which the sample remaining was dried to a constant weight and its weight determined.

A is the weight of sample bone dry before washing.

B is the weight of sample bone dry after washing.

$$\text{Percent Fine Aggregate passing \#100 sieve} = \frac{(A-B)100}{A}$$

Sample Computation:

Test I $A = 782.72$ $B = 765.76$

$$\text{Percent of Fine Aggregate Passing} = \frac{782.72-765.76}{782.72} = 2.17\%$$

Results of Tests:

	A	B	Percent of Fine Aggregate Passing Sieve
Test I	782.72	765.76	2.17
Test II	988.33	975.95	1.25
Test III	996.19	987.35	1.79
Average Results			1.77

Conclusions: As can be seen from the results, the cement retained was 1.61% and the fine aggregate passing was 1.77%. The difference being 0.16%.

The fact that more fine aggregate passes than cement is retained undoubtably produces an error in the test to determine the constituents of fresh concrete. The error; being as small as it is, and because of the uncertainty of where a correction should be applied; was omitted entirely from this series of tests.

In the tests to determine the constituents of fresh concrete three batches of concrete will be analyzed. The batches will be of varying consistencies as: dry, medium, and wet. Approximately the same w/c ratio will be used in each batch. The size of the batch was chosen to be 3000 gm. The size of a sample to be analyzed in the field would be the same.

Batch A

	Gross Wt.	Corrections	Net Wts.	Prop.
Cement	500		500	1
Fine Agg.	1000	-11.2	988.8	1.98
Coarse Agg.	1500	-18.8	1481.2	2.96
Water	221.5	30.0	251.5	.503

Batch B

	Gross Wt.	Corrections	Net Wts.	Prop.
Cement	500		500	1
Fine Agg.	875	-9.8	884.8	1.77
Coarse Agg.	1250	-15.6	1265.6	2.53
Water	221.5	25.4	246.9	.494

Batch C

	Gross Wt.	Corrections	Net Wts.	Prop.
Cement	700		700	1
Fine Agg.	1050	-11.8	1038.2	1.48
Coarse Agg.	1400	-17.5	1382.5	1.98
Water	310	29.3	339.3	.485

Now the actual tests can be run. The proper weights of cement, fine and coarse aggregates, and water are weighed out with the apparatus set for weighing in air. The fine aggregate was chosen as all material passing a No. 4 sieve, and coarse aggregate was that retained on the same. These materials were mixed in a pan and then washed into the copper pail. Care was taken to wash all the concrete into the pail, and at the same stirring the contents to prevent the trapping of any air in the mixture. The pail with its contents was then allowed to stand for a period of at least one minute. After settling it was immersed in the large boiler and the excess water flowed through the run-off spout till it ceased of its own accord. It is important not to make any immersed weighings untill all the excess water has run off: otherwise an error will be incurred in the weighings. When this weight has been taken the contents of the pail are poured onto the nested No. 4 and 100 seives. The No. 100 sieve is a special one with openings around the sides. The material on the seives is now washed untill all the cement has been washed out and the coarse and fine aggregates are seperated on the two sieves. The coarse aggregate is returned to the pail and its weight immersed obtained. Then the fine aggregate is added and the weight of the two combined is found, (immersed weights). The immersed weight of the fine aggregate is calculated by subtracting the weight of the coarse aggregate from the weight of the two combined. Similarly the weight of the cement, immersed, is obtained by subtracting the the weight of the combined aggregates from the weight of the of the total mix. The dry weights are then calculated from the following formula:

$$\text{Dry Weight} = \frac{\text{Specific Gravity}}{\text{Specific Gravity} - 1} \text{(Immeresed Weight)}$$

The weight of the water in the batch is found by the difference between the total batch weight in air and the sum of the calculated dry weights of the cement and aggregates. Now the computations of the w/c ratio and cement and coarse and fine aggregates proportions can be made.

The following page contains a chart showing the results of the tests, on the three batches; a determination of the constituents of fresh concrete.

SUMMARY OF TEST ANALYSIS

Gal./bag of Cement

Cement - Fine Agg. - Coarse Agg.

Test No.	Batch A	Batch B	Batch C
Actual	5.68 1-1.98-2.96	5.57 1-1.77-2.46	5.47 1-1.48-1.98
1.	5.54 1-1.94-2.87	5.39 1-1.70-2.46	5.44 1-1.45-1.94
2.	5.69 1-1.93-2.88	5.58 1-1.73-2.44	5.36 1-1.47-1.96
3.	5.77 1-1.95-2.94	5.51 1-1.74-2.47	5.39 1-1.43-1.91
4.	5.77 1-1.96-2.91	5.57 1-1.73-2.47	5.44 1-1.46-1.94
5.	5.67 1-1.90-2.48	5.64 1-1.74-2.47	5.42 1-1.45-1.93
6.	5.77 1-1.90-2.87	5.56 1-1.75-2.48	5.48 1-1.47-1.95
7.	5.52 1-1.89-2.90	5.45 1-1.72-2.45	5.45 1-1.44-1.92
8.	5.79 1-1.97-2.94	5.56 1-1.73-2.47	5.51 1-1.48-1.95
9.	5.57 1-1.92-2.87	5.56 1-1.73-2.46	5.45 1-1.45-1.94
10.	5.84 1-1.96-1.92	5.68 1-1.75-2.48	5.53 1-1.49-1.97

TEST 1 - MIX A

Cement............	=	500.0	g.
Fine Aggregate....	=	988.8	g.
Coarse Aggregate..	=	1481.2	g.
Water.............	=	251.5	g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed.......................... = 1898.2 g.

Wt. of Coarse Agg. immersed.......................... = 935.2 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1553.1 g.

Wt. of Fine Agg. immersed............................ = 619.9 g.

Wt. of Cement immersed............................... = 345.6 g.

Calculations

Cement $\quad \frac{3.1}{3.1 - 1} \ (345.6) = 510.7$ g.

Fine Agg. $\quad \frac{2.68}{2.68 - 1} \ (620.0) = 992.0$ g.

Coarse Agg. $\quad \frac{2.74}{2.74 - 1} \ (935.2) = \underline{1468.2}$ g.

Total 2970.9 g.

Water
3221.5 - 2970.9 250.6

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.491	1.00	1.94	2.87

TEST 2 - MIX A

Cement............ = 500.0 g.
Fine Aggregate.... = 988.8 g.
Coarse Aggregate.. = 1481.2 g.
Water............ = 251.5 g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed.......................... = 1896.1 g.

Wt. of Coarse Agg. immersed.......................... = 936.8 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1551.4 g.

Wt. of Fine Agg. immersed............................ = 614.6 g.

Wt. of Cement immersed............................... = 344.7 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (344.7) = 510.2 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (614.6) = 983.4 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (936.8) = 1470.8 g.

Total 2964.4 g.

Water
3221.5 - 2964.4 257.1

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.504	1.00	1.93	2.88

TEST 3 - MIX A

Cement............ =	500.0	g.
Fine Aggregate.... =	988.8	g.
Coarse Aggregate.. =	1481.2	g.
Water............. =	251.5	g.

Wt. of test sample in air.............................. =	3221.5 g.
Wt. of test sample immersed............................ =	1895.2 g.
Wt. of Coarse Agg. immersed............................ =	940.0 g.
Wt. of Coarse Agg. plus Fine Agg. immersed............. =	1555.0 g.
Wt. of Fine Agg. immersed.............................. =	615.0 g.
Wt. of Cement immersed................................. =	340.2 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (340.2) = 503.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (615.0) = 984.0 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (940.0) = 1475.8 g.

Total 2963.3 g.

Water
3221.2 - 2963.3 257.9 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.511	1.00	1.93	2.94

TEST 4 - MIX A

Cement............	=	500.0	g.
Fine Aggregate....	=	988.8	g.
Coarse Aggregate..	=	1481.2	g.
Water.............	=	251.5	g.

Wt. of test sample in air.............................. = 3221.5 g.

Wt. of test sample immersed........................... = 1895.5 g.

Wt. of Coarse Agg. immersed........................... = 935.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1554.5 g.

Wt. of Fine Agg. immersed............................. = 618.8 g.

Wt. of Cement immersed................................ = 341.0 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (341.0) = 504.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (618.8) = 990.1 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (935.7) = 1469.0 g.

Total 2963.8 g.

Water
3221.5 - 2963.8 257.7

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.511	1.00	1.96	2.91

TEST 5 - MIX A

Cement............	=	500.0 g.
Fine Aggregate....	=	988.8 g.
Coarse Aggregate..	=	1481.2 g.
Water.............	=	251.5 g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed.......................... = 1895.5 g.

Wt. of Coarse Agg. immersed.......................... = 933.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1546.3 g.

Wt. of Fine Agg. immersed............................ = 612.6 g.

Wt. of Cement immersed............................... = 349.2 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (349.2) = 516.8 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (612.6) = 980.2 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (933.7) = 1465.9 g.

Total 1962.9 g.

Water

3221.5 - 2962.9 259.6

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.502	1.00	1.90	2.84

TEST 6 - MIX A

Cement............	=	500.0 g.
Fine Aggregate....	=	988.8 g.
Coarse Aggregate..	=	1481.2 g.
Water.............	=	251.5 g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed.......................... = 1983.2 g.

Wt. of Coarse Agg. immersed.......................... = 936.4 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1546.6 g.

Wt. of Fine Agg. immersed............................ = 610.2 g.

Wt. of Cement immersed............................... = 346.6 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (346.6) = 513.0 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (610.2) = 976.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (936.4) = 1470.1 g.

Total 2959.4 g.

Water

3221.5 - 2959.4 262.1 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.511	1.00	1.90	2.87

TEST 7 - MIX A

Cement............ = 500.0 g.
Fine Aggregate.... = 988.8 g.
Coarse Aggregate.. = 1481.2 g.
Water............. = 251.5 g.

Wt. of test sample in air............................. = 3221.5 g.

Wt. of test sample immersed........................... = 1899.6 g.

Wt. of Coarse Agg. immersed........................... = 936.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed............ = 1550.5 g.

Wt. of Fine Agg. immersed............................. = 613.8 g.

Wt. of Cement immersed................................ = 349.1 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (349.1) = 516.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (613.8) = 982.1 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (936.7) = 1470.6 g.

Total 2969.4 g.

Water
3221.5 - 2969.4 252.1 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.489	1.00	1.89	2.90

TEST 8 - MIX A

Cement............	=	500.0	g.
Fine Aggregate....	=	988.8	g.
Coarse Aggregate..	=	1481.2	g.
Water.............	=	251.5	g.

Wt. of test sample in air............................	=	3221.5 g.
Wt. of test sample immersed..........................	=	1895.5 g.
Wt. of Coarse Agg. immersed..........................	=	938.6 g.
Wt. of Coarse Agg. plus Fine Agg. immersed...........	=	1556.3 g.
Wt. of Fine Agg. immersed............................	=	617.7 g.
Wt. of Cement immersed...............................	=	339.2 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (339.2) = 502.0 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (617.7) = 988.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (938.6) = $\underline{1473.6}$ g.

Total 2963.9 g.

Water

3221.5 - 2963.9 257.6 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.513	1.00	1.97	2.94

TEST 9 - MIX A

Cement............ = 500.0 g.
Fine Aggregate.... = 988.8 g.
Coarse Aggregate.. = 1481.2 g.
Water............. = 251.5 g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed.......................... = 1896.0 g.

Wt. of Coarse Agg. immersed.......................... = 935.3 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1549.7 g.

Wt. of Fine Agg. immersed............................ = 614.4 g.

Wt. of Cement immersed............................... = 346.3 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (346.3) = 512.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (614.4) = 983.0 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (935.3) = 1468.4 g.

Total 2963.9 g.

Water
3221.5 - 2963.9 257.6

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.493	1.00	1.92	2.87

TEST 10 - MIX A

Cement............	=	500.0	g.
Fine Aggregate....	=	988.8	g.
Coarse Aggregate..	=	1481.2	g.
Water.............	=	251.5	g.

Wt. of test sample in air............................ = 3221.5 g.

Wt. of test sample immersed......................... = 1893.7 g.

Wt. of Coarse Agg. immersed......................... = 938.0 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1553.5 g.

Wt. of Fine Agg. immersed........................... = 615.5 g.

Wt. of Cement immersed.............................. = 340.2 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (340.2) = 503.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (615.5) = 984.8 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (938.0) = 1472.7 g.

Total 2961.0 g.

Water
3221.5 - 2961.0 260.3 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.503	1.00	1.98	2.96
Calculated	.517	1.00	1.96	2.92

TEST 1 - MIX B

Cement............	=	500.0 g.
Fine Aggregate....	=	884.8 g.
Coarse Aggregate..	=	1265.6 g.
Water............	=	246.9 g.

Wt. of test sample in air.............................. = 2897.3 g.

Wt. of test sample immersed........................... = 1698.6 g.

Wt. of Coarse Agg. immersed........................... = 805.1 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1351.7 g.

Wt. of Fine Agg. immersed............................. = 546.6 g.

Wt. of Cement immersed................................ = 346.9 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (346.9) = 513.4 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (546.6) = 874.6 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (805.1) = 1264.0 g.

Total 2652.0 g.

Water

2897.3 - 2652.0 245.3 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.478	1.00	1.70	2.46

TEST 2 - MIX B

Cement............	=	500.0 g.
Fine Aggregate....	=	884.8 g.
Coarse Aggregate..	=	1265.6 g.
Water.............	=	246.9 g.

Wt. of test sample in air.............................. = 2897.3 g.

Wt. of test sample immersed........................... = 1693.4 g.

Wt. of Coarse Agg. immersed........................... = 799.1 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1349.3 g.

Wt. of Fine Agg. immersed............................. = 550.2 g.

Wt. of Cement immersed................................ = 344.3 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (344.3) = 510 0 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (550.2) = 880.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (799.1) = 1254.6 g.

Total 2644.9 g.

Water
2897.3 - 2644.9 252.4 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.495	1.00	1.73	2.44

TEST 3 - MIX B

Cement.............. = 500.0 g.
Fine Aggregate.... = 884.8 g.
Coarse Aggregate.. = 1265.6 g.
Water............. = 246.9 g.

Wt. of test sample in air.............................. = 2897.3 g.

Wt. of test sample immersed.......................... = 1696.5 g.

Wt. of Coarse Agg. immersed.......................... = 800.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1352.8 g.

Wt. of Fine Agg. immersed............................ = 552.1 g.

Wt. of Cement immersed............................... = 343.7 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (343.7) = 508.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (552.1) = 883.4 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (800.7) = 1257.1 g.

Total 2649.2 g.

Water
2897.3 - 2649.2 248.1 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.489	1.00	1.74	2.47

TEST 4 - MIX B

Cement............	=	500.0 g.
Fine Aggregate....	=	884.8 g.
Coarse Aggregate..	=	1265.6 g.
Water.............	=	246.9 g.

Wt. of test sample in air..............................	= 2897.3	g.
Wt. of test sample immersed..........................	= 1694.4	g.
Wt. of Coarse Agg. immersed..........................	= 800.3	g.
Wt. of Coarse Agg. plus Fine Agg. immersed...........	= 1350.7	g.
Wt. of Fine Agg. immersed............................	= 550.4	g.
Wt. of Cement immersed...............................	= 343.7	g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (343.7) = 508.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (550.4) = 880.6 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (800.3) = 1256.5 g.

Total 2645.8 g.

Water
2897.3 - 2645.8 251.5

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.494	1.00	1.73	2.47

TEST 5 - MIX B

Cement............ = 500.0 g.
Fine Aggregate.... = 884.8 g.
Coarse Aggregate.. = 1265.6 g.
Water............. = 246.9 g.

Wt. of test sample in air............................ = 2897.3 g.

Wt. of test sample immersed.......................... = 1692.8 g.

Wt. of Coarse Agg. immersed.......................... = 798.9 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1349.9 g.

Wt. of Fine Agg. immersed............................ = 551.0 g.

Wt. of Cement immersed............................... = 342.9 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (342.9) = 507.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (551.0) = 881.6 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (798.9) = 1254.3 g.

Total 2643.4 g.

Water

2897.3 - 2643.4 253.9

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.500	1.00	1.74	2.47

TEST 6 - MIX B

Cement............ =	500.0	g.
Fine Aggregate.... =	884.8	g.
Coarse Aggregate.. =	1265.6	g.
Water............. =	246.9	g.

Wt. of test sample in air........................... = 2897.3 g.

Wt. of test sample immersed......................... = 1695.5 g.

Wt. of Coarse Agg. immersed......................... = 800.2 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1353.5 g.

Wt. of Fine Agg. immersed........................... = 553.3 g.

Wt. of Cement immersed.............................. = 342.0 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (342.0) = 506.2 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (553.3) = 885.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (800.2) = 1256.3 g.

Total 2647.8 g.

Water

2897.3 - 2647.8 249.5 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1,77	2.53
Calculated	.493	1.00	1.75	2.48

TEST 7 - MIX B

Cement............ =	500.0 g.
Fine Aggregate.... =	884.8 g.
Coarse Aggregate.. =	1265.6 g.
Water............ =	246.9 g.

Wt. of test sample in air............................ = 2897.3 g.

Wt. of test sample immersed.......................... = 1697.0 g.

Wt. of Coarse Agg. immersed.......................... = 800.3 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1350.5 g.

Wt. of Fine Agg. immersed............................ = 550.2 g.

Wt. of Cement immersed............................... = 346.5 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (346.5) = 512.8 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (550.2) = 880.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (800.3) = 1256.5 g.

Total 2649.6 g.

Water
2897.3 - 2649.6 247.7 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.483	1.00	1.72	2.45

TEST 8 - MIX B

Cement............ = 500.0 g.
Fine Aggregate.... = 884.8 g.
Coarse Aggregate.. = 1265.6 g.
Water............. = 246.9 g.

Wt. of test sample in air.............................. = 2897.3 g.

Wt. of test sample immersed........................... = 1694.7 g.

Wt. of Coarse Agg. immersed........................... = 800.1 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1350.8 g.

Wt. of Fine Agg. immersed............................. = 550.7 g.

Wt. of Cement immersed................................ = 343.9 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (343.9) = 509.0 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (550.7) = 881.1 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (800.1) = 1256.2 g.

Total 2646.3 g.

Water

2897.3 - 2646.3 251.0 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.493	1.00	1.73	2.47

TEST 9 - MIX B

Cement............ = 500.0 g.
Fine Aggregate.... = 884.8 g.
Coarse Aggregate.. = 1265.6 g.
Water............ = 246.9 g.

Wt. of test sample in air............................ = 2897.3 g.

Wt. of test sample immersed.......................... = 1694.6 g.

Wt. of Coarse Agg. immersed.......................... = 799.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1350.4 g.

Wt. of Fine Agg. immersed............................ = 550.7 g.

Wt. of Cement immersed............................... = 344.2 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (344.2) = 509.4 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (550.7) = 881.1 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (799.7) = 1255.5 g.

Total 2646.0 g.

Water

2897.3 - 2646.0 251.3 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.493	1.00	1.73	2.46

TEST 10 - MIX B

Cement............	=	500.0	g.
Fine Aggregate....	=	884.8	g.
Coarse Aggregate..	=	1265.6	g.
Water............	=	246.9	g.

Wt. of test sample in air..........................	=	2897.3	g.
Wt. of test sample immersed........................	=	1691.5	g.
Wt. of Coarse Agg. immersed........................	=	797.9	g.
Wt. of Coarse Agg. plus Fine Agg. immersed...........	=	1350.5	g.
Wt. of Fine Agg. immersed..........................	=	552.6	g.
Wt. of Cement immersed.............................	=	341.0	g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (341.0) = 504.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (552.6) = 884.2 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (797.9) = 1252.7 g.

Total 2641.6 g.

Water

2897.3 - 2641.6 255.7 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.494	1.00	1.77	2.53
Calculated	.504	1.00	1.75	2.48

TEST 1 - MIX C

Cement............ = 700.0 g.
Fine Aggregate.... = 1038.2 g.
Coarse Aggregate.. = 1382.5 g.
Water............. = 339.3 g.

Wt. of test sample in air.......................... = 3460.0 g.

Wt. of test sample immersed........................ = 1995.1 g.

Wt. of Coarse Agg. immersed........................ = 874.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed.......... = 1516.1 g.

Wt. of Fine Agg. immersed.......................... = 641.4 g.

Wt. of Cement immersed............................. = 479.0 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (479.0) = 708.9 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (641.4) = 1026.2 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (874.7) = 1373.3 g.

Total 3108.4 g.

Water
3460.0 - 3108.4 341.6 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.482	1.00	1.45	1.94

TEST 2 - MIX C

Cement............	= 700.0	g.
Fine Aggregate....	= 1038.2	g.
Coarse Aggregate..	= 1382.5	g.
Water............	= 339.3	g.

Wt. of test sample in air............................ = 3460.0 g.

Wt. of test sample immersed.......................... = 2005.5 g.

Wt. of Coarse Agg. immersed.......................... = 881.4 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1529.4 g.

Wt. of Fine Agg. immersed............................ = 648.0 g.

Wt. of Cement immersed............................... = 476.1 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (476.1) = 704.6 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (648.0) = 1036.8 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (881.4) = 1383.8 g.

Total 3125.2 g.

Water

3460.0 - 3125.2 334.8

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.475	1.00	1.47	1.96

TEST 3 - MIX C

Cement............ = 700.0 g.
Fine Aggregate.... = 1038.2 g.
Coarse Aggregate.. = 1382.5 g.
Water............. = 339.3 g.

Wt. of test sample in air............................ = 3460.0 g.

Wt. of test sample immersed.......................... = 2000.8 g.

Wt. of Coarse Agg. immersed.......................... = 873.9 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1516.0 g.

Wt. of Fine Agg. immersed............................ = 642.1 g.

Wt. of Cement immersed............................... = 484.8 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (484.8) = 717.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (642.1) = 1027.4 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (873.9) = 1372.0 g.

Total 3116.9 g.

Water

3460.0 - 3116.9 343.1 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.478	1.00	1.43	1.91

TEST 4 - MIX C

Cement............ = 700.0 g.
Fine Aggregate.... = 1038.2 g.
Coarse Aggregate.. = 1382.5 g.
Water............. = 339.3 g.

Wt. of test sample in air.......................... = 3460.0 g.

Wt. of test sample immersed........................ = 2001.4 g.

Wt. of Coarse Agg. immersed........................ = 874.2 g.

Wt. of Coarse Agg. plus Fine Agg. immersed......... = 1522.5 g.

Wt. of Fine Agg. immersed.......................... = 648.3 g.

Wt. of Cement immersed............................. = 478.9 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (478.9) = 708.8 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (648.3) = 1037.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (874.2) = 1372.5 g.

Total 3118.6 g.

Water
3460.0 - 3118.6 341.4 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.482	1.00	1.46	1.94

TEST 5 - MIX C

Cement............	=	700.0 g.
Fine Aggregate....	=	1038.2 g.
Coarse Aggregate..	=	1382.5 g.
Water.............	=	339.3 g.

Wt. of test sample in air........................... = 3460.0 g.

Wt. of test sample immersed......................... = 1997.1 g.

Wt. of Coarse Agg. immersed......................... = 873.6 g.

Wt. of Coarse Agg. plus Fine Agg. immersed.......... = 1518.1 g.

Wt. of Fine Agg. immersed........................... = 644.5 g.

Wt. of Cement immersed.............................. = 479.0 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (479.0) = 708.9 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (644.5) = 1031.2 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (873.6) = 1371.6 g.

Total 3111.7 g.

Water

3460.0 - 3111.7 348.3 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.481	1.00	1.45	1.93

TEST 6 . - MIX C

Cement............	=	700.0 g.
Fine Aggregate....	=	1038.2 g.
Coarse Aggregate..	=	1382.5 g.
Water.............	=	339.3 g.

Wt. of test sample in air........................... = 3460.0 g.

Wt. of test sample immersed......................... = 2000.4 g.

Wt. of Coarse Agg. immersed......................... = 877.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1523.7 g.

Wt. of Fine Agg. immersed........................... = 646.0 g.

Wt. of Cement immersed.............................. = 476.7 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (476.7) = 705.5 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (646.0) = 1033.6 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (877.7) = 1378.0 g.

Total 3117.1 g.

Water

3460.0 - 3117.1 342.9 g.

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.486	1.00	1.47	1.95

TEST 7 - MIX C

Cement............ =	700.0 g.
Fine Aggregate.... =	1038.2 g.
Coarse Aggregate.. =	1382.5 g.
Water............. =	339.3 g.

Wt. of test sample in air.............................. =	3460.0	g.
Wt. of test sample immersed........................... =	1999.4	g.
Wt. of Coarse Agg. immersed........................... =	874.5	g.
Wt. of Coarse Agg. plus Fine Agg. immersed........... =	1517.2	g.
Wt. of Fine Agg. immersed............................. =	642.7	g.
Wt. of Cement immersed................................ =	482.2	g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (482.2) = 713.7 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (642.7) = 1028.3 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (874.5) = 1373.0 g.

Total 3115.0 g.

Water
3460.0 - 3115.0 345.0

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.483	1.00	1.44	1.92

TEST 8 - MIX C

Cement............. = 700.0 g.
Fine Aggregate.... = 1038.2 g.
Coarse Aggregate.. = 1382.5 g.
Water.............. = 339.3 g.

Wt. of test sample in air.............................. = 3460.0 g.

Wt. of test sample immersed.......................... = 1999.7 g.

Wt. of Coarse Agg. immersed.......................... = 873.7 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1524.4 g.

Wt. of Fine Agg. immersed............................ = 650.7 g.

Wt. of Cement immersed............................... = 475.3 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (475.3) = 703.4 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (650.7) = 1041.0 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (873.7) = 1371.7 g.

Total 3116.1 g.

Water

3460.0 - 3116.1 343.9

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.489	1.00	1.48	1.95

TEST 9 - MIX C

Cement............	=	700.0 g.
Fine Aggregate.....	=	1038.2 g.
Coarse Aggregate..	=	1382.5 g.
Water.............	=	339.3 g.

Wt. of test sample in air.............................. = 3460.0 g.

Wt. of test sample immersed.......................... = 2000.5 g.

Wt. of Coarse Agg. immersed.......................... = 876.0 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1520.7 g.

Wt. of Fine Agg. immersed............................ = 644.7 g.

Wt. of Cement immersed............................... = 479.8 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (479.8) = 710.1 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (644.7) = 1031.5 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (876.0) = 1375.3 g.

Total 3116.9 g.

Water

3460.0 - 3116.9 343.1

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.483	1.00	1.45	1.94

TEST 10 - MIX C

Cement............ =	700.0	g.
Fine Aggregate.... =	1038.2	g.
Coarse Aggregate.. =	1382.5	g.
Water............ =	339.3	g.

Wt. of test sample in air.............................. = 3460.0 g.

Wt. of test sample immersed........................... = 2000.4 g.

Wt. of Coarse Agg. immersed........................... = 878.0 g.

Wt. of Coarse Agg. plus Fine Agg. immersed........... = 1528.5 g.

Wt. of Fine Agg. immersed............................. = 650.5 g.

Wt. of Cement immersed................................ = 471.9 g.

Calculations

Cement $\frac{3.1}{3.1 - 1}$ (471.9) = 698.4 g.

Fine Agg. $\frac{2.68}{2.68 - 1}$ (650.5) = 1040.8 g.

Coarse Agg. $\frac{2.74}{2.74 - 1}$ (878.0) = 1378.5 g.

Total 3117.7 g.

Water

3460.0 - 3117.7 342.3

Proportions

	Water	Cement	Fine Agg.	Coarse Agg.
Actual	.485	1.00	1.48	1.98
Calculated	.490	1.00	1.49	1.97

CONCLUSION

It might be well to first analyze the error discovered in these tests.

I will first consider the percent error in the w/c ratio for the various batches. In Batch A the greatest error was 2.8% with an average of 1.7%. It is also interesting to note whether their variation was over or under the true w/c ratio. In this particular batch there was an average deviation of 0.12 gal under the true ration in gallons per sack of cement. The average deviation over the true ratio was 0.09 gal. In batch B the greatest error encountered was 2.9% with an average error of 1.8%. The average deviation under the true w/c ratio was found to be 0.06 gal and over the true ratio 0.05 gal. In Batch C the greatest percent error was 2.0% with an average error of 0.8%. The average deviation under the true w/c ratio was 0.08 gal and over this ratio was 0.03 gal per bag of cement.

I might try to account for this error. Since the weighings were only carried out with accuracy to 0.5 gm you cannot expect the w/c ratio to check to the nearest 0.05 gm. Perhaps the real cause for this error is due to neglecting the difference of percent cement retained and the percent sand passing the No. 100 sieve. Since the difference was only 0.16% it was not considered in the analysis of fresh concrete. I suppose a portion of the error might be attributed to this fact. If a correction was used for this difference it would, in calculating the dry weights, decrease the value obtained for the weight of the cement. This would, in turn, increase the value for the amount of fine aggregate calculated. The amount of water, which is the value obtained by subtracting the sum of the calculated dry weights from the weight of the total sample, would be approximately the same as found in the tests due to a cancelling effect of the decrease in cement and increase in the fine aggregate having on the sum of the calculated dry weights. Even though the amount of water would remain the same the cement is increased and this would increase the w/c ratio.It should be noted in the error encountered in the actual test results for this ratio, most of the test values were below the true w/c ratio; therefore if a corredtion were applied it would bring the calculated ratios closer to the true ratios.

Now the error in coarse and fine aggregates will be considered. In Batch A the greatest deviation from the true proportions are in the fine aggregate 0.09 with an average of 0.05. For the coarse aggregate the greatest deviation was 0.12, its average being 0.07. In Batch B the greatest deviation for the fine aggregate was 0.07 with an average of 0.04. For the coarse aggregate the greatese deviation from the true proportions was0.09 with an average of 0.02. In Batch C the greatese deviation was 0.08 for the fine, its average being 0.02. In the case of the coarse aggregate the greatest deviation from the true proportion was 0.07 and the average was 0.04.

It is interesting to note that for all three batches the deviations from the true proportions are all in the same direction. They are all less than the true proportions. I shall try to account for this fact in the fine aggregate lay referring back to the w/c ratio. It was found there that upon washing a sample batch more fine aggregate passes the No. 100 sieve than there is cement retained. There is a difference of 0.16% which would increase the amount of the fine aggregate. This in turn would increase the calculated proportion of fine aggregate and perhaps bring it closer to its true proportion. Because of this same difference of 0.16% the amount of cement being decreased would also bring the proportions of fine aggregate closer to its true value. In the case of the coarse aggregate this decrease in cement content would increase the proportion of coarse aggregate; thus bringing it closer to its true proportions. Perhaps some of the error can be laid to the specific gravity of the coarse aggregate. From the tests in its determination the unusally large values should be noted. Although only three tests were entered in this paper, several determinations were run and the results were the same; therefore, I hardly believe any error in the proportion of coarse aggregate can can be due to the wrong determination of its specific gravity.

The water to cement ratio, if calculated to the nearest $\frac{1}{4}$ gal. per bag of cement, is accurate enough for nearly all construction specifications. The results of the series of tests conducted in this paper are well within this allowance and presents positive proof that the Dunagan Test To Determine the Constituents of Fresh Concrete can accurately be used in analyzing total batches; therefore, if a representative sample is chosen in the field and this test is run with accuracy the results will be representative of the congrete analyzed. It is necessary to emphasize the coordination of the tests for specific gravity with the tests to determine the constituents of fresh concrete. Also, the difficulty of securing a sample which is representative of all constituents, is obvious, however, if through specifications the net water os tp gpvern the quality of the concrete, this test nicely eliminates a lot of worry about them.

If this Dunagan Test were used in the field, it would save time and money in carrying out specifications. Since the test apparatus is of such size and construction it can be readily used in the field control of concrete. It furnishes an accurate check of the design specifications for the quality of concrete as well as a check on the method of palcing to prevent segregation.

The Dunagan method seems to meet the necessary requirements for a test of this sort in that:

(a) It furnishes accurate and dependable data.

(b) The test may be completed rapidly.

(c) The apparatus is suitable for field use.

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