EVALUATION OF A CHEMICAL TECHNIQUE TO DETERMINE WATER AND CEMENT CONTENT OF FRESH CONCRETE

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This report presents information obtained from an evaluation of a chemical procedure for determining the water and cement content of a concrete in the plastic state. The procedure uses chloride ion titration to determine water content and flame photometry (calcium signature) to determine cement content. This study evaluated the procedure to determine if it could be used to estimate concrete strength potential and to define to what extent test results are influenced by aggregate type, aggregate moisture conditions, aggregate absorption capacity, concrete mix proportions, mix time, and time of sampling. The fieldworthiness of the system was also evaluated. Results indicate that the procedure can rapidly (approximately 15 min) determine the water and cement content of fresh concrete and that it can be used to predict strength potential with an accuracy equal to that of predicting strength from known mix proportions. Aggregate type was the only major concrete parameter that significantly influenced test results. Although aggregate moisture condition, mix proportions, and length of mixing time also influenced test results, their influences were minor. The field tests have indicated that the system is fieldworthy and mobile.

•INSPECTION and testing procedures currently being used to determine the quality of concrete involve a time lag between concrete placement and the evaluation of concrete quality (compression or beam tests). In addition, the current tests do not relate directly to either the material or the construction parameters that influence concrete quality.

This study evaluated the potential of a chemical technique originally developed by Kelly and Vail of the Greater London Council for rapidly determining the water and cement content of fresh concrete (1). The study determines if the procedure can be used to estimate concrete strength potential and defines to what extent test results are influenced by aggregate type, aggregate moisture conditions, aggregate absorption capacity, concrete mix proportions, mix time, and time of sampling. The fieldworthiness of the system was also evaluated.

PROCEDURE FOR DETERMINING WATER AND CEMENT CONTENT

The selection of analytical techniques for determining water and cement content was based on the criterion that the test should be rapid (<15 min), cheap, fieldworthy, and safe.

Water Content Determination

The method for water content determination is based on the theory that water in fresh concrete is available for intermixing with aqueous solutions. Thus, if an aqueous solution is of known strength and is not absorbed by the aggregate or the cement, the volume of water in a concrete sample can be determined analytically by determining the concentration of the intermixed solution. That is, if A is the volume of water in the mix, B and S_1 are the volume and strength respectively of the aqueous solution, and S_2 is the strength of the intermixed solution, then

$$B \times S_1 = (A + B)S_2 \tag{1}$$

From equation 1, A can be calculated if B and S_1 are fixed and S_2 is measured. To measure the strength of the intermixed solution, the Volhard back-titration method is used with sodium chloride as the solute. When the concrete contains chloride from other sources, the procedure requires the use of both a sample and a blank. The Volhard back-titration method, with its white to reddish-brown end point, has the advantage of being accurate, rapid (average time required 7 min 30 s), and simple enough for use by persons without analytical experience.

Figure 1 shows the equipment required for determination of water content. The equipment consists of a mechanical shaker; two wide-mouthed plastic bottles; 10-ml, 5-ml, 2.5-ml, and 2-ml constant-volume dispensers; two 50-ml and one 10-ml automatic pipettes; one 100-ml burette; two 50-ml volumetric pipettes; two 500-ml volumetric flasks; and two 500-ml Erlenmeyer flasks.

The procedure for water determination is as follows:

1. Weigh out two separate 1-kg samples of concrete and place each sample in a wide-mouthed bottle. Add 500 ml of 0.5 N sodium chloride solution to one bottle (sample) and 500 ml of distilled water to the other bottle (blank).
2. Seal the bottles and place them in a mechanical shaker; operate it for 3 min.
3. Remove the bottles from the shaker and allow the contents to settle for 3 min.
4. Pipette 50-ml samples of clear supernatant liquid from the sample and blank bottles and add them to separate Erlenmeyer flasks. To each flask (sample and blank) add 10 ml of 50 percent nitric acid, 2 ml of nitrobenzene, and 5 ml of ferric alum; shake them well.
5. Determine the chloride content of the sample and blank flasks by adding excess silver nitrate (50 ml of 0.5 N $AgNO_3$ for sample and 10 ml of 0.5 N $AgNO_3$ for blank) and by back-titrating with 0.05 N potassium thiocyanate (Volhard back-titration).
6. Record the quantity of potassium thiocyanate required to reach the white to reddish-brown end point in both the sample and the blank. Use Figure 2 to determine the water content of the mix. [The quantity of KCNS (ml) required for sample titration plus the back-titration of the blank (100 minus the KCNS required for blank titration) equals the abscissa of Figure 2.]

Cement Content Determination

The cement determination technique is based on the assumptions that (a) cement can be dispersed in water and held uniformly in suspension so that a representative sample can be obtained; (b) a quantitative solution of the cement in nitric acid can be achieved by adding cement to the acid while it is rapidly stirred without external heat; and (c) that calcium can be determined by a flame photometer in relatively high concentrations in the nitric acid solutions without prior removal of silica and the sesquioxides.

Figure 1 shows the equipment required for the cement tests. The apparatus for preparing and sampling the cement-water suspension consists of a nest of sieves (No. 4 and No. 50) over a side-agitator domestic washing machine and three automatic pipettes. One pipette collects the constant volume cement-water sample from the washing machine; the others dilute the sample with nitric acid and water. An ordinary domestic high-speed stirrer (milk-shake type) provides agitation for dissolving the cement suspended in the acid solution. A flame photometer is used to determine the calcium (cement) concentration.

Briefly, the major steps for cement determination are as follows:

Figure 1. Equipment used in the Kelly-Vail procedure for determining the water and cement content of fresh concrete.

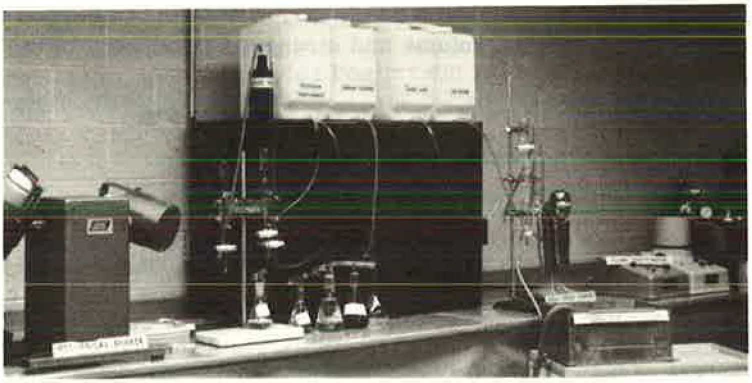


Figure 2. Results of water analysis.

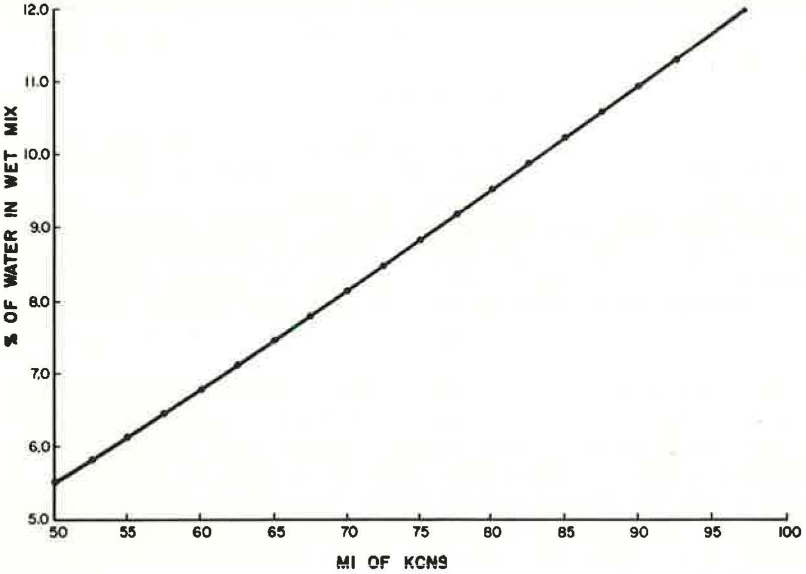
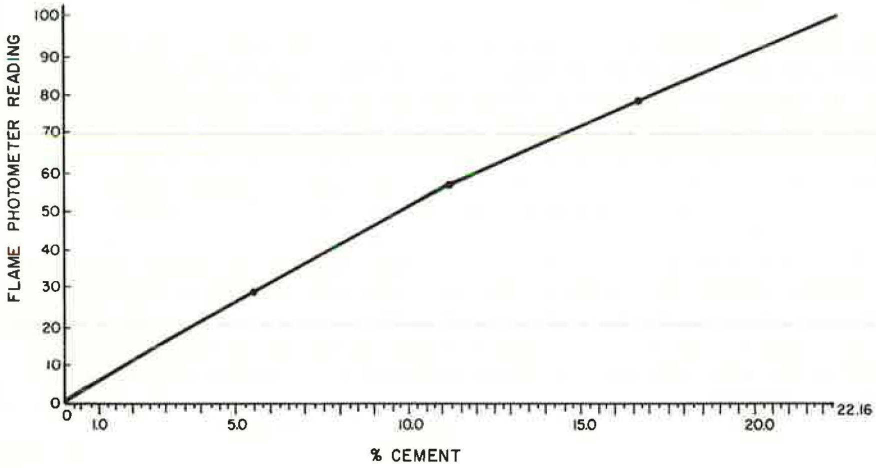


Figure 3. Results of cement analysis.



1. Fill the washing machine with 37.8 liters of tap water; place nest of sieves over the machine; start the agitator, and pump it to recirculate water.
2. Place a 1-kg concrete sample on the nest of sieves, and wash the cement from aggregate particles with the recirculating hose.
3. Allow agitation-recirculation operation to continue for 3 min. Attach the small hose to the automatic pipettes, and then clamp the recirculating hose nozzle so that the cement suspension will flow through the small hose and fill the automatic pipette (125 ml).
4. Empty the sample of cement suspension into a mixing cup, and wash down the pipette with 10 ml of 5 percent nitric acid from the upper pipette. Concurrently, dilute the acid-cement solution with 300 ml of tap water from the third pipette.
5. Stir the contents of mixing cup on high-speed mixer for 3 min.
6. Calibrate the flame photometer with a calcium standard and measure the calcium content of solution in the mixing cup. See Figure 3 for converting the readout to the cement content. (The calcium standard is prepared to equal 1.5 g/liter of cement, approximately 0.94 g/liter of $CaCO_3$.) The average time for a cement determination by an experienced operator is 7 min 10 s.

LABORATORY AND FIELD TESTS

Laboratory Tests

The laboratory test series evaluated three aggregate combinations, three mix proportions, two mix times, and two aggregate moisture conditions. The three aggregate combinations were Maryland quartz (coarse and fine), sand and gravel, and sand and crushed limestone (Figure 4). The mix proportions (Table 1) represented approximately 3,000, 4,500, and 6,000-psi (20.7, 31.0, and 41.4-MPa) concretes. A standard mix time of 5 min was used for each of the three mixes, and a second 4,500-psi (31.0-MPa) mix was tested by using a 45-min mix time. The two aggregate moisture conditions were air dried and saturated with some surface moisture.

Batches of 2 ft^3 (0.06 m^3) were used for all the series of tests. This was sufficient for a slump test and six 6 by 12-in. (15 by 30-cm) cylinders, in addition to the two 10-lb (4.54-kg) samples used for the water-cement analysis.

A complete standard water-cement analysis was run on both samples. The companion 6 by 12-in. (15 by 30-cm) cylinders were moist cured, three were broken at 7 days, and three were broken at 28 days.

Field Tests

Field tests were conducted at two construction sites by evaluating the mobility, reliability, and field worthiness of the system.

The test equipment was transported in a ready-to-use configuration in a pickup truck with a camper shell (Figure 5). To be operational, the self-contained unit requires only water from an external source.

The field tests evaluated ready-mix delivered concrete of three aggregate combinations and three mix designs. The aggregate combinations were lightweight coarse aggregate and sand, siliceous gravel and sand, and calcareous gravel and sand. The mix designs represented a 3,500-psi (24.1-MPa) structural lightweight concrete and a 4,500 and 3,000-psi (31.0 and 20.7-MPa) normal-weight concrete. [The actual batch proportions were not checked for the 3,500 and 4,500-psi (24.1 and 31.0-MPa) mixes because the batch plant was remote from the construction site and the water-cement test setup.]

The test procedure consisted of obtaining a water-cement content test sample from the same concrete that was used to prepare standard quality control cylinders. A complete water-cement analysis was run on all samples.

Figure 4. Aggregate gradations used in concrete tests.

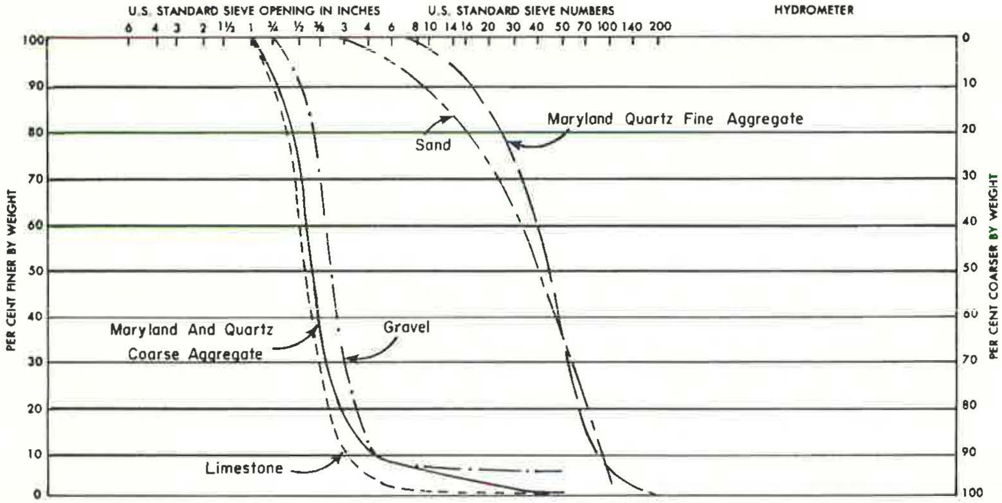


Table 1. Analysis of laboratory mixes.

Batch No.	Aggregate Type[a]	Coarse Aggregate (percent) Moisture	Coarse Aggregate (percent) Mix Proportion	Fine Aggregate (percent) Moisture	Fine Aggregate (percent) Mix Proportion	Cement Mix Proportion (percent)	Water (percent) Free	Water (percent) Total	Water-Cement Ratio[b]	Strength (psi) 7-Day Avg	Strength (psi) 28-Day Avg	Slump (in.)	Mix Time (min)
1	MdQ	0.56	48.5	7.86	24.6	18.40	8.39	8.73	0.45	3,600	4,785	—	5
2	MdQ	0:96	49.0	12.01	31.4	14.24	8.80	9.18	0.62	2,590	3,585	—	5
3	MdQ	0.41	49.3	15.38	34.4	11.71	8.85	9.25	0.75	1,470	2,420	—	5
4	MdQ	0.44	49.0	16.74	32.6	14.24	8.64	9.02	0.61	2,640	3,910	—	45
5	L-S	1.30	41.8	6.20	31.4	19.55	8.74	9.62	0.45	5,258	6,460	—	5
6	L-S	1.40	42.1	6.30	36.0	15.14	8.54	9.47	0.56	4,250	5,494	8.0	5
7	L-S	1.20	42.4	6.40	38.4	12.57	8.53	9.49	0.68	2,700	4,061	—	5
8	L-S	1.30	42.1	5.70	35.9	15.14	8.42	9.35	0.56	4,062	5,382	5.5	45
9	L-S	0.10	41.8	0.40	29.9	19.55	7.91	8.80	0.40	5,612	6,910	6.5	5
10	L-S	0.09	42.1	0.40	34.0	15.14	8.02	8.95	0.53	4,310	5,335	8.5	5
11	L-S	0.10	42.4	0.50	36.2	12.57	8.08	9.02	0.64	3,024	4,085	8.0	5
12	L-S	0.10	42.1	0.40	34.0	15.14	8.02	8.96	0.53	4,062	5,215	3.0	45
13	MdQ	0.07	49.0	0.15	28.5	14.24	7.89	8.28	0.55	3,431	4,290	4.5	5
14	MdQ	0.05	49.0	0.15	28.5	14.24	7.88	8.27	0.55	3,349	4,005	1.5	45
15	G-S	3.12	34.6	3.67	33.2	23.70	9.00	10.59	0.38	6,550	7,460	6.0	5
16	G-S	3.32	35.0	3.69	39.8	16.84	9.12	10.80	0.54	4,186	5,390	9.0	5
17	G-S	3.33	35.2	3.00	42.9	13.49	9.04	10.76	0.67	2,730	3,930	9.5	5
18	G-S	3.20	34.9	4.26	40.4	16.79	8.97	10.65	0.53	4,304	5,220	4.0	45
19	G-S	0.36	34.6	0.22	32.3	23.62	7.97	9.61	0.34	6,733	7,670	1.0	5
20	G-S	0.32	34.9	0.21	38.8	16.79	7.98	9.69	0.48	4,710	5,750	4.5	5
21	G-S	0.32	35.2	0.19	41.7	13.48	8.01	9.77	0.59	3,215	4,140	3.5	5
22	G-S	0.27	34.9	0.21	38.8	16.79	7.96	9.68	0.47	4,740	5,770	1.0	45

Note: 1 psi = 6.9 kPa. 1 in. = 2.5 cm.

[a] MdQ = Maryland quartz coarse (absorption capability = 0.35 percent) and Maryland quartz fine (absorption capability = 0.75 percent). L-S = crushed limestone coarse (absorption capability = 1.30 percent) and river sand fine (absorption capability = 1.15 percent). G-S = gravel coarse (absorption capability = 3.65 percent) and river sand fine (absorption capability = 1.15 percent).

[b] Based on free-water content.

Figure 5. Field test equipment.

ANALYSIS AND DISCUSSION OF TEST RESULTS

Laboratory Tests

Data obtained from the water and cement tests on concrete samples were analyzed to determine overall accuracy and the influence of aggregate type, aggregate moisture condition, concrete mix proportions, mix time, and sampling on test results. The percentage of recovery (measured values divided by actual values) was used as the basis of comparison, and the water tests were related to both the free and total water content of the mixes.

Table 2 gives the laboratory test results of the water and cement content of the concrete samples. Table 3 indicates that, for all batches, the average recovery was 97.8 percent for cement, 96.6 percent for free water, and 85.7 percent for total water. The associated standard deviations were 8.1 percent for cement, 4.4 percent for free water, and 3.7 percent for total water. The overall accuracies, including all the variables, were 8 and 4 percent respectively for the cement and water tests. Table 3 also indicates that the accuracies increased when each aggregate type was analyzed separately: The error in the cement tests decreased to about 6 percent, and the error in the water tests decreased to about 3.5 percent.

An analysis of variance was used to determine which parameters influenced the amounts of cement and water recovered. The parameters included in the analysis were aggregate type (coarse and fine quartz, coarse limestone and river sand, and coarse gravel and river sand), aggregate moisture condition (saturated plus some surface moisture and air dried), mix proportions [representing nominal 3,000, 4,500, and 6,000 psi (20.7, 31.0, and 41.4 MPa), mix time (5 and 45 min), and sampling sequence (sample obtained for water and cement content analysis before or after cylinder samples taken].

Results indicate that both the water and cement tests are sensitive at the 95 percent confidence level and are significantly influenced by the aggregate type. Average recovery values for cement ranged from a low of 93.5 percent for the quartz aggregate to a high of 104.8 percent for the limestone aggregate. Average water recovery values based on free water varied from 94.2 percent for quartz aggregate to 100.2 percent for gravel; conversely, water recovery based on total water varied from 83.5 percent for gravel to 89.1 percent for quartz.

The high cement-recovery value for the limestone aggregate concrete was attributed to the rock dust and limestone fines that passed through the nest of sieves above the washing machine. To confirm this, a cement test was conducted on a limestone aggregate sample representative of the limestone gradation and weight (420 g) used in the concrete specimens. The 420 g of limestone are equivalent to 12.5 g of cement or an error of 1.25 percent of cement. When this 1.25 percent is substracted from the cement test results, the mean cement recovery value for the limestone aggregate concrete is reduced to 96.59 percent.

In evaluating results of the water tests on the concrete samples, it was concluded that the test results are slightly more representative of free water than of total water; the recovery values based on free water are in all cases much closer to 100 percent.

Strength Prediction Based on Laboratory Results

Data obtained from the laboratory tests on concrete samples indicate that the chemical technique for determining water and cement content can be used directly to estimate the strength potential of a concrete mix. Figure 6 shows the 28-day cylinder strengths versus the water-cement ratios obtained in all batches tested. Figure 7 shows the 28-day cylinder strengths versus the actual water-cement ratios. [Actual water content is based on (a) free water available assuming the aggregates become saturated and (b) the quantity of mix water modified by the moisture content of the aggregate for each concrete batch.]

Table 2. Laboratory test results of water and cement content of concrete samples.

	Batch Proportions (percent)				Test Results (percent)		Recovery (percent)		
Batch No.	Free Water	Total Water	Cement	Sample No.	Water	Cement	Free Water	Total Water	Cement
1	8.39	8.73	18.40	1	7.45	17.75	88.8	85.3	96.5
				2	8.15	17.80	97.1	93.4	96.7
2	8.80	9.18	14.24	1	7.80	13.30	88.6	85.0	93.4
				2	8.15	12.25	92.6	88.8	86.0
3	8.85	9.25	11.71	1	8.81	11.40	99.5	95.2	97.4
				2	8.45	12.65	95.5	91.4	108.0
4	8.64	9.02	14.24	1	8.15	13.25	93.2	84.7	93.3
				2	8.15	12.15	93.2	84.7	85.3
5	8.74	9.62	19.55	1	7.80	19.62	89.2	81.1	100.3
				2	8.15	20.05	93.2	84.7	102.6
6	8.54	9.47	15.14	1	7.80	16.87	91.3	82.4	111.4
				2	8.44	17.25	98.8	89.1	113.9
7	8.53	9.49	12.57	1	8.15	13.30	95.5	86.1	105.8
				2	8.15	13.38	95.5	86.1	106.4
8	8.42	9.35	15.14	1	7.47	15.58	88.7	79.9	102.9
				2	7.80	16.30	92.6	83.4	107.7
9	7.91	8.80	19.55	1	7.80	20.15	98.6	88.6	103.1
				2	7.80	19.15	98.6	88.6	98.0
10	8.02	8.95	15.14	1	7.65	16.50	95.4	85.5	109.0
				2	7.95	16.15	99.1	88.8	106.7
11	8.08	9.02	12.57	1	7.65	12.80	94.7	84.8	101.8
				2	8.15	14.40	100.9	90.3	114.6
12	8.02	8.95	15.14	1	7.45	15.00	92.9	83.1	99.1
				2	7.45	14.20	92.9	83.1	92.2
13	7.89	8.28	14.24	1	7.30	12.25	92.5	88.2	86.0
				2	7.30	13.80	92.5	88.2	96.9
14	7.88	8.27	14.24	1	7.45	12.25	94.5	90.1	86.0
				2	7.80	13.75	99.0	94.3	96.9
15	9.00	10.59	23.70	1	8.45	24.70	93.9	79.8	104.2
				2	8.45	21.25	93.9	79.8	89.7
16	9.12	10.80	16.84	1	8.82	16.45	96.7	81.7	97.9
				2	8.82	16.20	96.7	81.7	96.2
17	9.04	10.76	13.49	1	9.50	13.00	105.1	88.3	96.4
				2	9.16	10.25	101.3	85.1	76.0
18	8.97	10.65	16.79	1	9.16	15.90	102.1	86.0	94.7
				2	9.16	15.97	102.1	86.0	95.1
19	7.97	9.61	23.62	1	7.96	22.85	99.7	82.1	96.7
				2	8.15	22.45	102.1	84.1	95.0
20	7.98	9.69	16.79	1	7.96	15.55	99.7	82.1	92.6
				2	8.15	15.45	102.1	84.1	92.0
21	8.01	9.77	13.48	1	8.15	12.95	101.7	83.4	96.1
				2	8.15	13.18	101.7	83.4	97.8
22	7.96	9.68	16.79	1	8.15	16.15	102.4	84.2	96.2
				2	8.15	14.80	102.4	84.2	88.1

Table 3. Statistical analysis of recovery values of concrete samples.

	All Batches		Batch 1-4, 13-14[a]		Batch 5-12[b]		Batch 15-22[c]	
Item	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Cement	97.79	8.06	93.53	6.77	104.77	5.96	94.03	6.03
Free water	96.56	4.40	94.17	3.68	94.87	3.62	100.23	3.25
Total water	85.70	3.74	89.11	3.82	85.35	3.09	83.50	2.27

[a] Maryland quartz aggregate. [b] Limestone-sand aggregate. [c] Gravel-sand aggregate.

Figure 6. Chemically determined water-cement ratio versus 28-day compressive strength for all batches.

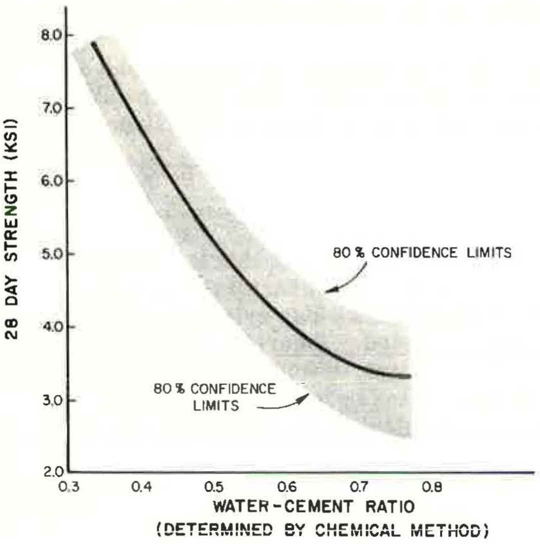


Figure 7. Actual water-cement ratio versus 28-day compressive strength.

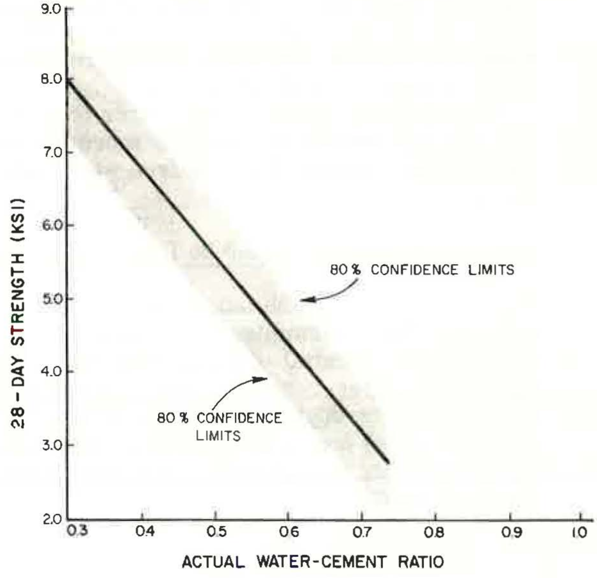


Table 4 gives the error associated with using the chemical technique to determine water and cement content as a measure of strength potential of a concrete. When all results are grouped together (Figure 6), the 80 percent confidence limits relating the chemically determined water-cement ratio to strength are ±780 psi (5.37 MPa). When results are grouped by aggregate type (Table 4), however, the confidence bands decrease to ±550, ±500, and ±350 psi (3.79, 3.44, and 2.41 MPa) for the quartz, gravel-sand, and limestone-sand aggregate combinations respectively. Similar trends and improvements were also noted when strengths were compared to actual water-cement ratios (Table 4).

Table 4 compares the confidence limits for predicting strength by the actual and the chemically determined water-cement ratios. This comparison indicates that when all three aggregate combinations are grouped together confidence bands for the actual and the chemically determined water-cement ratios are nearly equal [±780 psi (5.37 MPa) for the chemically determined versus ±720 psi (4.96 MPa) for the actual]. When the comparison is made individually by aggregate type, the spread of the confidence limits for the actual water-cement ratio values is less for two of the three aggregate combinations.

Another variable evaluated was strength within a batch. Within-batch strength variations are normally associated with discrepancies in mixer efficiency, fabricating, curing, and testing. The within-batch variation obtained for the complete concrete test series was 196 psi (1.35 MPa) for the 80 percent confidence limit.

All the above analyses indicate that the chemical procedure for determining water and cement content can be used to predict strength potential with an error no greater than if strength determination were based on the actual water-cement ratios of the mixes.

Field Tests

The field evaluations of the testing technique and the mobile unit have indicated that the unit can be transported with the automatic pipettes mounted in a ready-to-use configuration on the camper doors. Only one major equipment deficiency was noted during the field tests, the sensitivity of the flame photometer to external light. The use of a hood and side shields around the flame photometer decreased the sensitivity, but, even with the hood and shield, calibrating and holding calibration during the determination of an unknown cement solution were difficult. Present procedures permit the operations of the flame photometer inside the camper.

Table 5 gives the results obtained from the field tests and compares them to those for the mix designs. For the water content test, results indicate excellent agreement between the test results and the mix designs. The average recovery and associated standard deviation for the water test were 99.62 percent and 7.52 percent respectively. The results from the cement test were not quite so encouraging. For the cement test, the average recovery was 94.39 percent and the standard deviation was 26.6 percent. It is assumed that the flame photometer's sensitivity to external light was partially responsible for the higher deviations. In addition, the last 11 tests were conducted on a calcareous aggregate (both coarse and fine) concrete, requiring an aggregate blank test for removing the aggregate influence on the cement test results. This added another variable to influence cement test results.

The water-cement ratios obtained from the field tests were plotted against 28-day control cylinders. Figure 8 shows the field tests overlayed on the laboratory water-cement ratio versus 28-day cylinder strengths. The vast majority (12 out of 16) of the field test results fell near or within the 80 percent confidence limits of the laboratory test results. Of the four that fell outside, three were from the calcareous aggregate concrete. Even though the field data base is small and quite limited, the results indicate the potential of using the chemically determined water and cement content as a field test in evaluating concrete strength potential.

Table 4. Errors in strength predictions based on chemical technique, 80 percent confidence limits.

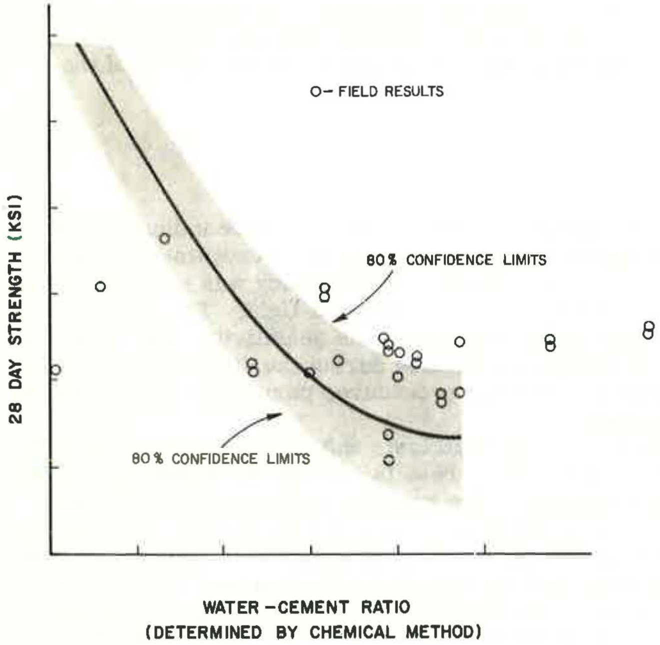
Sample Group	Error in Predicting Actual Water-Cement Ratio	Error in Test Data (psi)	Actual Strength Prediction (psi)
All	±0.078	±780	±720
Quartz	±0.060	±550	±175
Limestone-sand	±0.025	±350	±480
Gravel-sand	±0.046	±500	±335

Note: 1 psi = 6.9 kPa.

Table 5. Field test results of water and cement content of concrete samples.

Test No.	Mix Proportions (percent)		Test Results (percent)		Recovery (percent)	
	Water	Cement	Water	Cement	Water	Cement
1	9.85	19.8	10.5	15.5	106.5	78.4
2	9.85	19.8	9.5	15.2	96.0	76.8
3	9.85	19.8	9.2	15.4	93.3	77.7
4	7.21	19.2	7.1	16.9	99.0	87.7
5	7.21	19.2	6.83	19.5	94.7	101.3
6	6.92	12.4	7.48	10.3	108.0	83.0
7	7.60	11.8	7.15	10.3	94.0	87.2
8	7.60	11.8	7.80	10.2	102.5	86.5
9	7.60	11.8	8.15	11.0	107.0	93.2
10	7.60	11.8	7.80	12.8	102.5	108.5
11	7.60	11.8	8.15	11.9	107.0	100.7
12	7.60	11.8	8.15	15.4	107.0	130.5
13	7.60	11.8	7.15	8.1	94.0	68.6
14	7.60	11.8	8.15	11.4	107.0	96.6
15	7.60	11.8	7.15	7.2	94.0	61.0
16	7.60	11.8	6.2	20.4	81.5	94.39

Figure 8. Chemically determined water-cement ratio versus 28-day compressive strength compared with field test results.



CONCLUSIONS

The results of this study indicate the following:

1. A chemical procedure has been developed that can rapidly (≈15 min) determine the water and cement content of a concrete in the plastic state.
2. The chemical procedure for determining water and cement content can be used to predict the strength potential of the concrete. The reliability of predicting strength by this procedure is nearly equal to that of predicting strength based on actual mix proportions.
3. Aggregate type, such as limestone, gravel, or quartz, significantly influences the results obtained from the chemical tests. Although the chemical method is also sensitive to aggregate moisture condition, mix proportions, and length of mix time, the degree of sensitivity is for all practical purposes insignificant.
4. Even though the chemical method is sensitive to the type of aggregate used, satisfactory results were obtained for concrete made from both gravel and limestone coarse aggregate.
5. The one major limitation of the chemical method is that the cement content technique decreases in accuracy if the fine aggregate or sand has a high calcium content. This occurs when a manufactured sand (crushed limestone) is used for the fine aggregate.
6. Field tests have indicated that the system is fieldworthy and mobile.

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