Rapid Test Methods for the Evaluation of Concrete Properties

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16. Abstract

The objective of the project was to place a CERL/Kelly-Vail testing unit and a microwave oven in the field to perform tests of plastic concrete on construction projects.

The CERL/K-V tests were to determine water and cement content of the concrete and were evaluated as a method of predicting 28-day concrete strength.

Although the water and cement contents can be determined with a reasonable degree of accuracy, there are too many variables involved in the field to accurately predict strength.

The microwave oven used in the defrost mode is a fast and accurate method to determine water content with a minimum of equipment and operator training.

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Rapid Test Methods for the Evaluation of Concrete Properties

Introduction

There is a recognized need in the construction industry for a rapid test method for the early evaluation of portland cement concrete properties. The Oregon State Highway Division uses the 28-day compressive strength of 6 in. x 12 in. (15.24 cm x 30.48 cm) concrete cylinders as a basis of acceptance of concrete going into highway projects, as do most other agencies and contractors. On many projects, a large quantity of concrete can be placed before the first cylinders are 28 days old. On Oregon highway projects the control of the concrete is tight enough that construction can usually proceed with confidence, but this is not always true. Then it would be desirable to have a simple, reliable, rapid test method on which to base an evaluation.

Kelly and Vail of the Greater London Council developed a system using chloride ion titration to determine water content and flame photometry to determine cement content of plastic concrete. The U. S. Army Construction Engineering Research Laboratory (CERL), under the guidance of P. A. Howdyshell, replaced the flame photometer with calcium titration for determining cement content. The calcium titration uses an EDTA (ethylenediaminetetraacetate) solution in the presence of a buffer and an eriochrome black T indicator.

For the project being discussed here, the CERL modified Kelly-Vail (CERL/K-V) procedures were used in combination with the microwave oven test for determining water content of fresh portland cement concrete. The recommendations of Robert Peterson, (1) Research Engineer, North Dakota State Highway Department, were followed for the microwave testing.

(1) Peterson, Robert T. and Dave Leftwich, "Determination of Water Content of Plastic Concrete Using a Microwave Oven", North Dakota State Highway Department, Bismarck, North Dakota, 1978.

As a separate but parallel project under a contract with the CERL, electronic analyzers were also used to determine cement and water content of concrete. This method uses the same principles used in the Kelly-Vail test but the chloride ion and the calcium concentrations are determined by the analyzers rather than by titration. The results from this testing are shown in the tabulated data included with this report.

Purpose

The purpose of the project was to put a CERL/K-V unit in the field to gather data from several construction projects. The transit-mix concrete arriving at the jobsites was analyzed for cement and water content by this process and for water content using the microwave oven. The findings by these methods and by the electronic analyzers are compared and evaluated.

Scope

In the Oregon work plan, it was estimated that 200 CERL/K-V tests and 100 microwave oven tests could be performed during one summer when students were available to help. These numbers turned out to be too ambitious for several reasons. The lab trailer was set up at a central location on I-205 right-of-way in East Portland where water and power were available. The trailer site was only a few minutes from several active projects from which concrete samples were taken. Even with several sources to draw from, concrete was not always available for testing. Occasionally samples were taken at a prestress yard but it was farther from the trailer site so more time was used for travel.

Also, a lot of time was spent troubleshooting the process and the equipment when an end point could not be reached in the titration procedure. Where it would have been necessary to average nearly four tests per day to reach the project goal, that number was seldom reached and never exceeded. A total of 104 CERL/K-V tests for water and cement content were performed and 51 determinations of water content using the microwave oven were made.

In 1976 the Construction Education and Research Foundation at Oregon State University, under a grant from the Associated General Contractors Foundation, entered into an agreement with CERL to assemble four Kelly-Vail units in trailers and place them on construction sites to collect data for CERL. One of the trailers, with most of the testing apparatus still intact, was later purchased by BHW Engineering in Roseburg, Oregon. When this project was undertaken, BHW agreed to rent their unit to us for a nominal fee.

For the microwave testing, a small and inexpensive Toshiba Model ER539BT microwave oven was purchased. This is rated at 400 watts but the oven cavity is less than one cubic foot. One salesman told us that ovens should be evaluated on the basis of watts per cubic foot and, although we never heard this from anyone else, it seemed reasonable.

Troubleshooting

Immediately after the Kelly-Vail trailer was obtained, it was temporarily set up at the Salem Materials Lab for outfitting and for operator training. Several tests were run using samples from laboratory mixes. There were no apparent problems with the tests and the water and cement content determined by the tests was reasonably close to the known content. Samples were then obtained from a local concrete supplier during the pouring of precast median barriers. During the CERL/K-V testing for cement content, no clear end point to the titration was achieved. While the normal end point color change is from wine red to deep blue, the change which occurred in this instance was to a deep purple. A large excess of

EDTA was added: *i.e.*, where a normal cement content was present, 110 to 140 ml would be used to produce an end point, here 200 ml of EDTA were added. An end point after addition of 200 ml would indicate 25 - 30% cement by weight. Clearly, this quantity of cement was not used. However, no clear end point was reached. After the sample had been set aside for 10 - 20 minutes the color changed to a deep blue.

The use of calcium chloride in the concrete was suspected, but after chemical analysis this was ruled out. A sample of commercial mix was obtained from a different local supplier whose aggregate source is close to that of the first supplier. The results were identical to the previous test.

At this point the trailer was moved to its permanent project location in Portland. The cause of the test breakdown was unknown at this time. Of the first 32 samples run, in 10 cases no end point was achieved. The samples which resulted in no end point came from five different sources and involved four different brands of cement. It was then that Dr. Paul Howdyshell of the CERL at Champaign, Illinois arrived in Portland with the intention of training an operator for the electronic analyzer method of Kelly-Vail testing. As the failure to achieve an end point was critical to the CERL/K-V test and he had not encountered the problem before, he decided to devote a portion of his time to it. Dr. Howdyshell and field personnel ran several concrete samples from various sources through the Kelly-Vail titration process and failed to achieve a clear end point in every case.

Project personnel went with Dr. Howdyshell to the Corps of Engineers Pacific Lab in Troutdale, Oregon to discuss the problem with their chemist. While there, it was determined that the reagents were satisfactory, the pH was in the proper range, and that the concentration of the solution was not a factor. However, there was still no clear end point.

While at the Corps of Engineers Lab a literature search was made for a possible solution. It was found that in the EDTA titrimetric method (2) several metal ions are cited that will interfere with the end point of the test. Ions above the following concentrations cause interference:

Ion	Concentration
Copper	2 ppm
Ferrous iron	20 ppm
Ferric iron	20 ppm
Manganese	10 ppm
Zinc	5 ppm
Lead	5 ppm
Aluminum	5 ppm
Tin	5 ppm
Alkalinity	30 ppm

In addition, strontium, barium, cobalt, nickel and mercury will cause interference. However, magnesium must be present in small quantities for the end point to be clear and distinct. In the titration of a cement solution this is no problem as cement contains about 1% magnesium.

Further research revealed several "masking agents" which, when added to the solution, will prevent those interfering ions from reacting with the EDTA or the indicator. In this case, where interfering ions were present, certain masking agents would allow a clear and distinct end point. Masking is defined as "the process in which a substance without physical separation of it or its reaction products, is so transformed that it does not enter into a particular reaction." (3)

(2) American Public Health Association, "Standard Methods for the Examination of Water and Wastewater", 13th edition (New York: APHA 1971) p. 84.

(3) Vogel, Arthur I., <u>A Textbook of Quantitative Inorganic Analysis</u> 3rd Edition (London: Longman 1968) p. 420 - 437.

The vehicle used for Eriochrome Black T dyestuff is triethanolamine which also serves to mask iron and aluminum. From the several masking agents cited in Vogel, it appeared that sodium cyanide and sodium sulfide would be sufficient to mask the remaining interfering ions and permit a good end point, if in fact this was the problem.

A solution of approximately one normal sodium cyanide and sodium sulfide was prepared. To facilitate field preparation, the formulation used was 0.5 g sodium cyanide and 0.5 g sodium sulfide dissolved in 10 ml water.

Fresh concrete samples were then obtained from the same sources as those tested earlier with no clear end point. These samples were again tested by the CERL/K-V method with no clear end point resulting. Simultaneous to the first sampling a duplicate sample was pulled and set aside. Following the failure to reach a clear end point on the first sample, five drops of the solution containing the masking agents were added to the duplicate sample and a titration was performed. In this sample solution, a very clear and distinct end point was reached at approximately the point expected for the known cement content. Every test sample in the study titrated for cement content after this had five drops of masking solution added to it and in every case, a clear end point was obtained.

At one stage of the CERL/K-V cement test the sample solution is acidic. Since the addition of sodium cyanide or sodium sulfide to an acidic solution will liberate highly poisonous gas, it is very important to combine the chemicals in the proper order. The normal procedure has 25 ml of acidic sample to which is added 10 ml of buffer solution which raises the pH to about 10. Then the indicator is added and the solution is titrated with EDTA. The masking solution must be added after the buffer solution has raised the pH or poisonous gas will be liberated. The proper order is:

1. acidic sample
2. buffer
3. masking solution
4. indicator
5. EDTA

Also, if the indicator is added to the sample before the masking solution (reversing Steps 3 and 4), the indicator will react with the interfering ions and no end point will result.

In many of the earlier tests where no end point had been reached, the water content portion of the CERL/K-V test was run anyway. The interfering ions seem to have no detrimental effect on the water content test. The addition of masking solution seemed also to have no effect on the water content test.

To determine what effect the amount of masking solution has on the determination of an end point, a dummy sample was created which was acidified and buffered. In the table below are the results of the titration with various amounts of masking solution (0.5 g sodium cyanide and 0.5 g sodium sulfide in 10 ml H_2O).

Masking Solution	End Point in ml EDTA	Quality of End Point
0	100.0 (stopped at this point)	No end point
5 drops	62.4	Good, clear, end point
3 drops	100.0	No end point
4 drops	100.0	No end point
5 drops	62.6	Good, clear, end point
7 drops	62.8	Good, clear, end point
10 drops	62.4	Good, clear, end point
15 drops	62.5	Good, clear, end point

Apparently, five drops is the minimum required at this concentration but a large excess can be added without detriment to the end point. At this time, field personnel were advised to increase the addition to ten drops.

Dr. Howdyshell indicated that in other similar CERL/K-V projects, he had not experienced this interference problem. After he left an attempt was made to determine the source of the interfering ions. A chemical analysis was run on the tap water which is used to wash the cement out of the plastic concrete sample. A duplicate analysis was run on a sample, just prior to titrating, which was known to have no end point without masking solution. The following table contains concentrations in ppm of certain ions in the two solutions.

Ion	Tap Water, ppm	Test Solution, ppm
Zinc	0.06	75.00
Iron	0.08	46.50
Copper	0.01	123.00
Magnesium	0.55	24.00
Manganese	0.02	0.70
Sodium	0.56	1.64

Obviously, the tap water was not a contributor to the interference (see table pg. 5). Since the chemical reagents were made with pure water, the interfering ions must have come from the concrete. Cement contains traces of some of these metals, but the same cements were used in samples which gave good end points. Lack of personnel prohibited further investigations. It can be tentatively concluded that the source of interference is from the aggregate, mixing water, or some unknown added ingredient of the concrete. Another possibility might be the accumulation of traces of interfering metal ions from several ingredients of the concrete. Most of the data on cement content reported to date has been determined by flame photometry. This could explain why this problem had not appeared before.

Test Results

In the Portland area, where the CERL/K-V lab was set up, there is considerable highway construction under contract. Although the structural concrete is furnished by commercial suppliers, the Oregon State Highway Division designs the mix and regularly checks the aggregate for gradation. There is a state inspector in the plant whenever concrete is being batched for highway projects. Records are kept of batch weights, additives, moisture content of aggregates, and mixing water.

When the truck arrives at the job site, the concrete is checked for slump, air content, unit weight and cylinders are cast. Part of the sample is taken back to the lab in a covered pan for the CERL/K-V and the microwave tests. All of the mix data and test results are tabulated in Tables 1 and 2. There are 17 different mix designs using aggregates from three sources and four brands of cements with Types I, II, and III being represented in different mixes. At first glance this may seem like an intolerable number of combinations, and perhaps it is. However, the aggregates are so similar, the different mix designs for a given class may vary only a few pounds. So it was felt that there was something to be gained from this variety of samples.

In Table 2, the "as batched" data, for all except prestress concrete, is calculated from actual and theoretical weights and is expressed as a percentage of total batch weight. The cement and aggregates are, of course, weighed and the added water is either weighed or metered. But the available water in the aggregate is estimated and may vary slightly from one load to the next. This is one of several variables introduced in the-field that are not present in the laboratory. The percentages of cement and water calculated for the different test methods are based on the actual unit weight of the concrete as determined for the yield test. In most cases the admixture is Master Builders air entraining agent (MBAE - 10) dosed at the rate of one ounce per sack of cement. Since this is a relatively constant factor, no particular attention is given to it.

In the case of prestress concrete, yield tests are not made in the field so the as batched data are theoretical. In other words, the mix weights used in the calculations are mix design weights and are not adjusted for varying moisture contents. This eliminates one variable in the calculations that affects the correlation from one test to another.

In Table 2 the results of the microwave oven testing are shown in Columns 10 through 13. Column 10 is total water recovered and would include at least part of the water absorbed by the aggregate. Column 12 adjusts for this absorbed water and considers only the water available for mixing. The moisture absorbed by the aggregate is routinely determined in the mix design process.

In the testing reported here, the correlation of water and cement contents by the different test methods is not very close. It is felt that part of this variation can be attributed to the absorbed moisture. The as batched moisture is calculated using available water only. The microwave oven drives out absorbed moisture so data from this procedure must be adjusted. The results of our testing seem to indicate that a portion of the absorbed moisture takes part in the CERL/K-V test. There was not time to do enough control testing in the central laboratory to verify this.

Another unknown variable that affects all tests is the water lost to evaporation. Since the samples are taken at the job site, rather than at the batch plant, the time interval from batching to testing is probably different in each case. Again, this would not affect the correlation of tests performed by the different methods on a given sample, but does affect the correlation of tests of different samples. Samples were transported in closed containers to minimize evaporation losses involved in testing but losses from the ready-mix trucks between batch plant and job site could be a significant factor.

There are several other variables that make evaluation difficult. Among these are air content, different brands and types of cement, different cement contents, and even different mix designs for a given cement content. Also, fly ash is used in some of the mixes. Although the aggregates are from different sources, they are all river gravels and have very similar absorption characteristics.

Since the ultimate objective of the project was to predict 28-day concrete strength, an attempt was first made to find a correlation between the water-cement ratio and strength. The correlation for the different methods of determining water and cement content ranged from poor to non-existent. This is shown in Table 3 where the various tests are grouped in different ways according to common factors. A correlation coefficient of 1 would be perfect. In some cases the number of tests with a common factor is too small to be considered representative. But, also, the correlation between the as batched water-cement ratio and concrete strength is highly variable and generally not very good. Since the as batched water and cement contents were used as the control, the validity of these correlations is questionable. No attempt was made to adjust the data according to air content. Figure 1 is graphic evidence of this lack of correlation. Here the as batched water-cement ratio for two mix designs are plotted against 28-day compressive strength. Both designs are for Class 3300 - 3/4 inch, 6.3 sack mix using aggregates from different sources and different cements. The mixes are designed to have a minimum 28-day strength of 3300 psi, 5 percent air, and 1 ounce per sack of MBAE - 10 additive. The measured air content ranged from 2.9 to 5 percent. All the concrete sampling and testing was done by the same two people and the test cylinders were cured in the same way; field cured for approximately 24 hours and then moist room cured until tested.

In order to get a little closer to the source of the data, the water and cement contents as determined by the different methods are expressed in terms of as batched proportions. This permits more tests to be grouped together. Forty-eight tests for which there are results by two methods (titration and microwave) are grouped on this basis. These tests are tabulated in Table 4. Mixes with fly ash are included. In Table 5 the fly ash mixes are removed with little effect. The calibration curve for the fly ash mix is based on equivalent cement so they should fall in the same range as the all cement mixes. There are only 19 tests with results by all three methods; titration, microwave, and analyzers. These are shown in Table 6.

The water recovered from the prestressed concrete is consistantly high and the cement content is low when put in terms of as batched proportions. The reason for this is not known but because of it the test results have not been included in Tables 4, 5, and 6. Results of prestressed concrete tests appear separately in Table 7.

A typical standard deviation for recovered water for all CERL/K-V tests is about 0.13. This translates to 4.3 to 4.6 gallons per cubic yard of concrete depending on the mix design. A standard deviation of 0.11 for cement recovered by CERL/K-V titration represents from 65 to 83 pounds per cubic yard.

Table 8 shows the results of limited testing done in the central laboratory to determine, primarily, if the microwave oven was suitable for the intended purpose. Trial batches of about 1200 grams were used, proportioned the same as some of the job mixes used in the field testing. In the first six tests, the aggregates were oven dried to substantially constant weight the same as they are for determining absorbed moisture during routine mix design.

During the drying of the trial batches in the microwave oven, the weight loss was greater than the moisture known to be present. This is similar to the findings by North Dakota investigators before they went to the defrost mode for drying the concrete. They attributed the extra weight loss to melting of the cement in the center of the sample. The samples dried here did indeed get very hot. Several of the pyrex dishes broke during drying.

For Tests 7 through 12, the aggregates were dried for a longer time before mixing and the cement was also oven dried. It is believed that at least part of the unexplained weight loss in the first six tests was due to moisture in the cement. When cement alone was subjected to drying in the microwave oven in the defrost mode, the weight loss was 0.7 percent.

Conclusions

The use of the CERL/Kelly Vail procedure for finding water and cement content of plastic concrete yields acceptable accuracy. But, in our view, to use water-cement ratio determined by this or any other method outside the laboratory as a predictor of 28-day compressive strength is not reliable. There are too many variables; air content, evaporation loss, temperature, etc. On a large project using the same mix design under the same conditions, the effect of these variables would be minimized.

As a quality control tool the procedure would surely have its place. However, it is a procedure that requires trained operators and some highly specialized equipment. Also, the shelf life of the reagents is limited.

For determining water content of concrete, it appears that drying the plastic mix in a microwave oven in the defrost mode will provide reliable results with a minimum of equipment and training. Some advance testing is required to determine the moisture absorbed by the aggregate, since the microwave will drive out all water, not just the free water available for mixing.

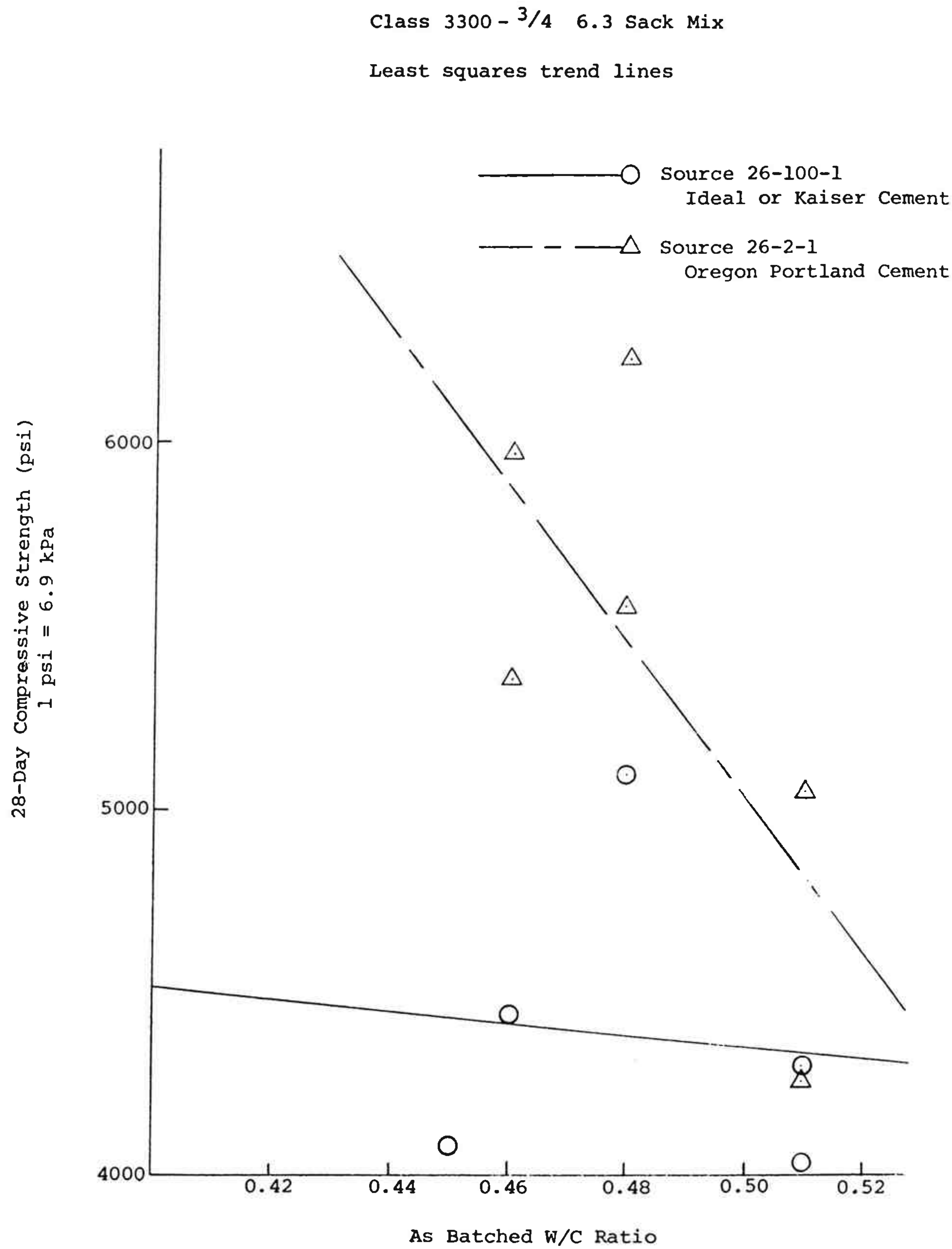

Figure 1. Strength vs. as batched water/cement ratio.

TABLE 1

Concrete Mix Data

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type *	8 oz/yd^3	9 Note
1	6-23	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.3	1
2	6-24	6.3 sack 3300-3/4	79-8929	26-100-1	Kaiser I&II	MB AE-10	6.3	
3	6-23	6.3 sack 3300-3/4	79-8929	26-100-1	Kaiser I&II	MB AE-10	6.3	
4	6-25	6.3 sack 3300-3/4	80-8089	Lewis Pit #2	Lonestar I	MB AE-10	6.3	
5	6-25	6.3 sack 3300-3/4	80-8089	Lewis Pit #2	Lonestar I	MB AE-10	6.3	
6	6-26	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C.	MB AE-10	6.3	
7	6-27	7.0 sack 4000-3/4	79-8930	26-100-1	Kaiser I&II	MB AE-10	7.0	
8	6-27	7.0 sack 4000-3/4	79-8930	26-100-1	Kaiser I&II	MB AE-10	7.0	
9	6-27	7.0 sack 4000-3/4	79-8930	26-100-1	Kaiser I&II	MB AE-10	7.0	
10	6-30	6.3 sack 3300-3/4	79-8929	26-100-1	Kaiser I&II	MB AE-10	6.3	
11	6-30	6.3 sack 3300-3/4	79-8929	26-100-1	Kaiser I&II	MB AE-10	6.3	

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 oz/yd^3	9 Note
12	6-30	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.3	
13	7-1	6.3 sack 3300-3/4	79-8929	26-100-1	Ideal I	MB AE-10	6.3	
14	7-1	6.3 sack 3300-3/4	79-8929	26-100-1	Ideal I	MB AE-10	6.3	
15	7-2	8.0 sack 6000-3/4		26-100-1	O.P.C. I	MB AE-10	6.3	
16	7-2	6.3 sack 3300-3/4	80-1500	26-2-1	Ideal I	MB AE-10	6.3	1
17	7-3	7.5 sack 5000-3/4	78-2987	26-2-1	Ideal I&II	MB AE-10	7.5	
18	7-3	7.5 sack 5000-3/4	78-2987	26-2-1	Ideal I&II	MB AE-10	7.5	
19	7-3	6.3 sack 3300-3/4	79-8929	26-100-1	Ideal I&II	MB AE-10	6.3	
20	7-7	6.3 sack 3300-3/4	78-2979	26-2-1	Kaiser I	MB AE-10	6.3	
21	7-8	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.3	1
22, 23, & 25 had no test cylinders for comparison, so Kelly Vail tests not recorded.								
24	7-9	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I&II	MB AE-10	6.3	

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 oz/yd^3	9 Note
26	7-9	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I&II	MB AE-10	6.3	
27	7-11	7.0 sack 4000-3/4	79-20483	26-100-1	Ideal I	MB AE-10	7.0	2
28	7-11	7.0 sack 4000-3/4	79-20483	26-100-1	Ideal I	MB AE-10	7.0	2
29	7-11	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
30	7-14	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.3	
31	7-14	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.3	
32	7-15	6.3 sack 3300-3/4	79-8929	26-100-1	Ideal	MB AE-10	6.3	
33	7-16	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
34	7-17	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I&II	MB AE-10	6.3	1
35	7-17	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	4
36	7-18	7.0 sack 4000-3/4	79-8930	26-100-1	Ideal I	MB AE-10	8.75	

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 oz/yd^3	9 Note
37	7-21	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.33	4
38	7-21	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal I	MB Pozzolith 100 XR	28.0	3
39	7-22	6.3 sack 3300-3/4	79-8933	26-100-1	Ideal I	MB AE-10	6.33	
40	7-22	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
41	7-24	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
42	7-24	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
43	7-24	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
44	7-25	7.0 sack 4000-3/4	79-8930	26-100-1	Ideal I	MB AE-10	8.75	
45	7-25	7.0 sack 4000-3/4	79-8930	26-100-1	Ideal I	MB AE-10	8.75	
46	7-29	7.0 sack 4000-3/4	79-8930	26-100-1	Ideal I	MB AE-10	7.0	
47	7-29	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.33	

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 Admixture oz/yd^3	9 Note
48	7-30	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
49	7-30	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
50	7-31	6.3 sack 3300-3/4	80-1957	26-2-1	O.P.C. I	MB AE-10	6.33	1
51	7-31	6.3 sack 3300-3/4	80-1957	26-2-1	O.P.C. I	MB AE-10	6.33	1
52	7-31	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.33	1
53	8-1	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
54	8-4	7.0 sack 4000-3/4	Field Off 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
55	8-5	7.2 sack 4000-3/4	79-8930	26-100-1	Ideal I	MB AE-10	7.0	
56	8-5	7.2 sack 4500-3/4	79-8931	26-100-1	Ideal I	MB AE-10	7.25	
57	8-5	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
58	8-6	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 oz/yd^3	9 Note
59	8-7	6.3 sack 3300-1.5	78-2979	26-2-1	O.P.C. I	MB AE-10	6.33	
60	8-7	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
61	8-8	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.33	
62	8-11	6.3 sack 3300-3/4	78-2984	26-2-1	O.P.C. I	MB AE-10	6.33	
63	8-11	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.33	1
64	8-11	6.3 sack 3300-3/4	80-1500	26-100-1	Ideal I	MB AE-10	6.33	1
65	8-12	6.0 sack 3300-1.5	79-15562	26-100-1	Ideal I	MB AE-10	6.0	5
66	8-12	6.0 sack 3300-1.5	79-15562	26-100-1	Ideal I	MB AE-10	6.0	5
67	8-13	6.3 sack 3300-1.5	78-2979	26-2-1	O.P.C. I	MB AE-10	6.33	
68	8-14	6.0 sack 3300-1.5	79-15562	26-100-1	Ideal I	MB AE-10	6.0	5
69	8-14		79-15562	26-100-1	Ideal I	MB AE-10	6.0	5

TABLE 1 - cont.

1 Test No.	2 Date	3 Mix Class	4 Lab No.	5 Aggregate Source	6 Cement	7 Admixture Brand/Type*	8 Admixture oz/yd^3	9 Note
92	8-25	7.5 sack 5000-3/4	78-2987	26-2-1	O.P.C. I	MB AE-10	7.5	
93	8-25	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
94	8-26	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	7.25	
95	8-26	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	9.0	
96	8-26	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	7.25	
97	8-27	7.5 sack 5000-1.5	78-2982	26-2-1	Ideal I	MB AE-10	7.5	
98	8-27	7.5 sack 5000-1.5	78-2982	26-2-1	Ideal I	MB AE-10	7.5	
99	8-28	7.0 sack 4000-3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith 100 XR	28.0	3
100	9-3	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	7.25	
101	9-3	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	7.25	
102	9-3	7.2 sack 4500-1.5	79-8935	26-100-1	Ideal I	MB AE-10	7.25	

TABLE 1 - cont.

1	2	3	4	5	6	7	8	9
Test No.	Date	Mix Class	Lab No.	Aggregate Source	Cement	Admixture Brand/Type*	Admixture Oz/yd^3	Note
103	9-4	7.0 sack 4500 - 3/4	Field Off. 1-2-80	26-100-1	Ideal III	MB Pozzolith	28.0	3
104	9-5	7.0 sack 5000 - 1.5	78-2982	26-2-1	Ideal I	MB AE-10	7.5	

* MB stands for Master Builders. AE-10 is an air entraining agent. Pozzolith XR is a water reducer and retarder.

Note 1. 6.3 sack equivalent fly ash mix has 503 lb. of cement and 111 lb. of fly ash/yd^3. Percent of cement reflects combined cement and fly ash.

Note 2. 7.0 sack equivalent fly ash mix has 559 lb. of cement and 124 lb. of fly ash/yd^3. Percent of cement reflects combined cement and fly ash.

Note 3. Tests performed on Morse Bros. 7.0 sack cement/yd^3 mix. No State mix design Lab No.

Note 4. CERL/K-V seemed to produce erratic results on hot days.

Note 5. This mix uses crushed coarse aggregate from source 5-4-1 and sand from source 26-100-1

Note 6. This mix uses crushed coarse aggregate from source 5-4-1 but has 7.0 sacks of cement/cy^3.

Note 7. This mix uses crushed coarse aggregate from source 26-100-1 and the mix design was made by Northwest Testing Lab.

TABLE 2

Concrete Mix Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			As Batched			CERL/K-V Titration			Microwave Total H_2O		Microwave Effective H_2O		CERL Electronic Analyzers					
Test No.	% Air	Slump in.	% H_2O	% Cem.	W/C Ratio	% H_2O	% Cem.	W/C Ratio	% H_2O	W/C Ratio	% H_2O	W/C Ratio	% H_2O	% Cem.	W/C Ratio	Cylinder Report No.	28 Day Strength (psi)	Note
1	3.6	4 1/4	7.2	15.1	0.48	7.2	15.6	0.46								C-36476	4235	1
2	4.2	3 1/4	6.9	15.0	0.46	8.2	14.6	0.56	8.9	0.59	7.2	0.48				C-36477	4440	
3	5.5	4 1/2	7.4	15.4	0.48	8.2	15.1	0.54	9.3	0.62	7.9	0.52				C-36478	4130	
4	5.2	6 3/4	7.3	15.3	0.48	7.5	No end point		6.2	0.42	4.9	0.33				C-36479	4013	
5	5.0	8 1/4	7.3	15.3	0.48	8.4	16.3	0.52								C-36480	3625	
6	4.2	6 1/4	7.4	15.2	0.49	8.5	No end point									C-36481	5176	
7	4.0	2 3/4	6.7	17.3	0.39	7.2	No end point		7.6	0.45	6.2	0.37				C-36482	5078	
8	4.2	4 1/4	6.8	17.4	0.39	8.0	15.9	0.50	8.7	0.51	7.2	0.43				C-36483	5088	
9	5.5	3	6.8	17.6	0.39	8.4	16.3	0.52								C-36484	4785	
10	4.5	4 1/4	7.9	15.4	0.51	7.9	No end point		8.6	0.57	7.2	0.48				C-36485	4298	
11	5.0	5 1/4	7.6	14.8	0.51	7.4	14.6	0.50	8.6	0.57	6.2	0.40				C-36486	4030	
12	4.2	6 1/4	7.7	15.2	0.51	8.5	14.7	0.57								C-36487	4263	
13	3.7	3	6.9	15.4	0.45	7.6	No end point		8.1	0.54	6.6	0.44				C-36488	4530	
14	3.2	3 1/4	6.8	15.0	0.45	6.4	13.3	0.48	8.7	0.58	7.3	0.48				C-36489	4383	
15	3.7	4 1/4	7.5	19.2	0.39	7.6	19.1	0.40	7.8	0.40	6.5	0.34				C-36490	6320	
16	2.8	5	6.7	15.0	0.45	6.8	18.3	0.37	9.0	0.57	7.5	0.50				C-36491	4580	1
17	3.6	4	6.9	18.1	0.38	5.9	15.3	0.39	7.8	0.51	6.6	0.36				C-36492	5205	
18	4.0	3 1/2	7.2	18.2	0.40	5.9	15.3	0.39	7.4	0.40	6.0	0.33				C-36493	5398	
19	3.8	4 1/4	7.1	15.7	0.45	7.7	15.8	0.49	9.6	0.64	8.2	0.55				C-36494	4080	
20	4.0	2	6.9	15.1	0.46	5.4	13.5	0.40	7.5	0.51	6.2	0.42				C-36495	4860	
21	2.5	2 1/2	7.2	15.9	0.45	6.0	No end point		6.8	0.52	5.7	0.41				C-36496	5195	1
22, 23 and 25 had no test cylinders for comparison data, so K-V tests not recorded.																		
24	3.8	3	7.3	15.3	0.48	6.1	12.5	0.49	7.6	0.51	6.1	0.41				C-36499	6225	
26	3.6	4	7.3	15.1	0.48	6.4	13.2	0.48	7.3	0.49	5.8	0.39				C-36500	5558	
27	4.2	3	7.1	18.0	0.39	6.3	16.0	0.39	8.3	0.59	6.8	0.47				C-36526	5238	2
28	4.2	1 1/4				6.4	18.8	0.34	7.8	0.54	6.5	0.45				C-36527	4798	2
29	3.5	4	7.1	18.2	0.39	6.8	No end point									C-36528	5968	

TABLE 2 (cont.)

Concrete Mix Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			As Batched			CERL/K-V Titration			Microwave Total H_2O		Microwave Effective H_2O		CERL Electronic Analyzers					
Test No.	% Air	Slump in.	% H_2O	% Cem.	W/C Ratio	% H_2O	% Cem.	W/C Ratio	% H_2O	W/C Ratio	% H_2O	W/C Ratio	% H_2O	% Cem.	W/C Ratio	Cylinder Report No.	28 Day Strength (psi)	Note
30	2.5	3 1/2	7.0	15.3	0.46	6.2	No end point		7.6	0.51	6.1	0.41				C-36529	6530	
31	3.6	2	7.0	15.3	0.46	6.2	No end point									C-36530	5968	
32	2.9	5 3/4	7.3	15.2	0.48	6.1	No end point									C-36531	5085	
33	1.5	4	5.8	16.6	0.35	6.4	14.4	0.35								C-36532	7995	3
34	4.6	3 3/4				6.4	12.4	0.52						8.7		C-36533	3833	1
35	4.5	3	6.9	18.2	0.38	6.5	No end point						9.4	18.3	0.51	C-36534	5480	4
36	3.5	2 1/2	7.3	17.0	0.43	-	No Kelly-Vail or Microwave tests					-				C-36535	5793	
37	4.6	5	6.8	15.1	0.45	4.3	12.8	0.34					8.4	14.4	0.58	C-36536	3833	4
38	1.6	2 1/4	5.4	16.6	0.33	6.6	14.0	0.47					7.8	14.6	0.54	C-36537	5798	3
39	3.2	5 1/4	7.1	14.8	0.47	7.9	12.3	0.51	6.1	0.41	4.6	0.31	9.0	13.6	0.67	C-36538	4555	
40	1.6	3	5.4	16.6	0.33	6.6	13.2	0.50					7.9	13.2	0.60	C-36539	7003	3
41	3.6	2 1/2	7.4	19.0	0.39	7.4	12.0	0.61	8.3	0.44	7.0	0.37	10.0	17.0	0.58	C-36540	5960	
42	3.6	1 3/4	7.3	19.0	0.40	7.5	16.0	0.46	9.5	0.50	8.2	0.43	9.1	16.1	0.57	C-36541	5560	
43	3.6	3	7.0	19.0	0.37	7.4	15.0	0.49					9.1	16.9	0.54	C-36542	5070	
44	4.0	4 1/2	7.2	16.8	0.43	7.2	14.2	0.51					8.4	14.4	0.58	C-36543	4675	
45	3.6	3 1/2	7.2	16.8	0.43	5.9	11.9	0.49								C-36544	3980	
46	3.0	3 1/2	8.0	17.2	0.47	8.0	12.7	0.62	9.0	0.53	7.7	0.45	9.7	15.8	0.61	C-36545	5818	
47	3.5	3	7.8	16.2	0.48	7.4	12.7	0.58					8.8	13.6	0.64	C-36546	5195	1
48	3.3	3 1/2	6.6	18.2	0.37	7.8	11.6	0.67					8.6	16.0	0.54	C-36547	5860	
49	3.9	4	6.5	17.6	0.37	8.6	16.8	0.51					8.8	15.4	0.57	C-36548	5500	
50	3.5	1 1/2	5.8	15.6	0.37	5.5	15.5	0.35	7.1	0.45	5.8	0.37	8.8	15.5	0.57	C-36549	5008	1
51	3.8	1	5.8	15.7	0.37	6.4	15.1	0.42	6.5	0.36	4.6	0.26	7.7	13.6	0.56	C-36550	5608	1
52	3.5	5 1/4	7.2	15.8	0.45	7.9	15.1	0.52					8.2	14.8	0.55	C-36601	3795	1
53	1.6	5 1/4	5.4	16.6	0.33	7.4	14.6	0.50								C-36602	6600	3
54	1.6	4	5.4	16.6	0.33	7.5	15.5	0.48					8.0	16.3	0.49	C-36603	6008	3
55	3.6	6	8.3	16.9	0.49	7.8	15.2	0.51	8.1	0.49	6.7	0.41	8.4	15.5	0.54	C-36604	5245	
56	4.0	2 3/4	7.3	17.3	0.42	7.3	15.5	0.47	7.3	0.42	5.9	0.34	9.0	21.0	0.43	C-36605	4510	
57	1.8	4	5.4	16.6	0.33	7.5	13.8	0.54								C-36606	6300	3
58	1.8	2	5.4	16.6	0.33	7.4	13.6	0.54	7.4	0.45	6.0	0.36	8.0	14.2	0.56	C-36607	5628	3
59	3.8	6	6.4	15.0	0.43	7.6	12.6	0.60	7.8	0.52	6.5	0.43	8.6	12.6	0.69	C-36608	4790	

TABLE 2 (cont.)

Concrete Mix Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			As Batched			CERL/K-V Titration			Microwave Total H_2O		Microwave Effective H_2O		CERL Electronic Analyzers					
Test No.	% Air	Slump in.	% H_2O	% Cem.	W/C Ratio	% H2O	% Cem.	W/C Ratio	% H_2O	W/C Ratio	% H_2O	W/C Ratio	% H_2O	% Cem.	W/C Ratio	Cylinder Report No.	28 Day Strength (psi)	Note
60	1.4	6	5.4	16.6	0.33	8.3	11.0	0.75					8.6	12.3	0.70	C-36609	5058	3
61	3.4	4 1/2	7.0	15.1	0.46	8.0	9.1	0.88					8.6	12.6	0.68	C-36610	5358	
62	4.5	3 1/2	7.6	15.0	0.51	7.3	12.1	0.61	7.7	0.51	6.3	0.42	7.8	13.6	0.58	C-36611	5053	
63	4.3	2	7.0	15.8	0.45	8.3	12.9	0.64	6.1	0.38	4.8	0.30	8.7	14.5	0.60	C-36612	4145	1
64	3.0	4 1/2	7.0	15.7	0.45	7.5	15.0	0.50								C-36613	4668	1
65	3.8	3 1/2	7.0	14.2	0.49	6.5	14.2	0.46	8.0	0.54	6.5	0.45	9.3	15.8	0.59	C-36614	4340	5
66	4.1	3	7.2	14.5	0.49	5.3	14.4	0.36					14.4	17.7	0.81	C-36615	3830	5
67	2.0	6	7.0	15.1	0.49	6.2	13.2	0.47					6.0	10.9	0.55	C-36616	5850	
68	4.0	3 3/4	6.4	14.2	0.45	7.8	12.1	0.64	8.6	0.61	7.2	0.52	8.6	18.3	0.47	C-36617	4158	5
69	4.0	2	6.5	14.2	0.46	8.4	12.9	0.65	9.3	0.69	8.0	0.57	8.9	14.9	0.60	C-36618	4090	5
70	3.6	3	6.3	16.6	0.38	8.2	15.3	0.54					9.4	17.6	0.54	C-36619	5020	6
71	1.6	5 1/2	5.4	16.6	0.33	6.7	14.6	0.46	8.1	0.60	6.8	0.41	8.3	17.7	0.47	C-36620	6968	3
72	1.6	3	5.4	16.6	0.33	7.0	14.6	0.47								C-36621	5478	3
73	4.9	2 1/2	6.4	14.2	0.45	8.0	8.0	1.00	8.0	0.58	6.6	0.48	9.4	15.9	0.60	C-36622	4125	5
74	3.8	3 3/4	6.8	14.2	0.48	8.0	15.3	0.53	9.4	0.66	8.1	0.57				C-36623	4133	5
75	4.7	3	6.6	14.2	0.46	7.3	14.8	0.49					9.3	19.8	0.47	C-36624	4123	5
76	3.2	3 1/2	6.6	14.0	0.47	7.5	10.7	0.70					8.9	14.4	0.62	C-26289	4292	5
77	3.7	2 1/4	7.0	14.2	0.49	9.1	13.4	0.68	8.3	0.60	6.8	0.49	8.9	25.0	0.36	C-36625	4678	5
78	3.7	3	7.0	13.9	0.50	7.9	11.0	0.72								C-37826	4298	5
79	3.5	2	6.9	16.5	0.42	8.4	15.6	0.54								C-37827	5638	6
80	5.0	5 1/2	6.5	18.3	0.36	7.6	15.7	0.36	7.3	0.40	6.0	0.33				C-37828	5210	
81	1.0	5 1/2	6.1	16.6	0.37	7.7	13.7	0.57								C-37829	5845	3
82	4.2	3 3/4	6.5	14.4	0.45	8.2	12.3	0.67	7.2	0.49	6.0	0.41				C-37830	4315	7
83	4.8	3	6.3	14.4	0.44	8.6	11.6	0.74								C-37831	4315	7
84	4.5	3	6.5	14.4	0.45	8.7	16.1	0.54								C-37832	4785	7
85	4.2	3 1/4	6.5	14.4	0.45	8.3	16.1	0.52								C-37833	4960	7
86	4.4	3	6.8	14.4	0.47	8.0	12.6	0.64								C-37834	4573	7
87	4.2	3 1/4	6.6	14.4	0.46	8.0	14.2	0.56	7.6	0.51	6.2	0.43				C-37835	4525	7

TABLE 2 (cont.)

Concrete Mix Data

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			As Batched			CERL/K-V Titration			Microwave Total H_2O		Microwave Effective H_2O		CERL Electronic Analyzers					
Test No.	% Air	Slump in.	% H_2O	% Cem.	W/C Ratio	% H_2O	% Cem.	W/C Ratio	% H_2O	W/C Ratio	% H_2O	W/C Ratio	% H_2O	% Cem.	W/C Ratio	Cylinder Report No.	28 Day Strength (psi)	Note
88	4.2	2 3/4	6.6	14.4	0.46	7.4	13.7	0.54	7.9	0.54	6.6	0.45				C-37836	4353	7
89	4.2	2 3/4	6.9	14.4	0.48	8.5	14.0	0.61								C-37837	4665	7
90	4.4	3	6.8	15.1	0.45	7.7	16.0	0.48	9.2	0.50	8.0	0.43				C-37838	5343	
91	4.2	4 1/2	6.8	15.1	0.45	8.1	15.0	0.54								C-37839	4963	
92	3.2	5 1/2	6.8	15.1	0.45	8.0	16.0	8.0	9.1	0.50	7.8	0.43				C-37840	5193	
93	1.6	3	7.8	16.6	0.47	6.1	12.3	0.50					6.6	13.6	0.49	C-37841	6288	3
94	3.5	2 1/4	6.5	15.9	0.41	6.2	15.5	0.40	7.0	0.41	5.8	0.34	8.7	15.8	0.55	C-37843	4973	
95	4.5	3 3/4	6.4	15.9	0.40	6.7	15.6	0.43	6.9	0.39	5.7	0.32	8.7	15.6	0.55	C-37844	4463	
96	4.2	3 3/4	6.6	17.2	0.38	7.5	12.6	0.60					8.7	15.8	0.55	C-37845	3878	
97	4.5	2	6.5	17.9	0.36	6.5	14.4	0.45	6.8	0.38	5.5	0.30	8.7	17.3	0.50	C-37846	5293	
98	4.0	3 3/4	7.0	18.2	0.38	6.7	19.0	0.35								C-37847	5548	
99	1.6	3 3/4	6.2	16.6	0.37	7.3	12.5	0.58								C-37848	5225	3
100	4.1	7	7.1	15.9	0.45	6.9	17.0	0.40	7.2	0.43	5.9	0.35				C-31565	4315	
101	4.1	3 3/4	6.7	15.9	0.42	6.3	17.0	0.37								C-31566	4763	
102	4.1	5	6.7	15.9	0.42	6.9	14.1	0.49					7.9			C-31567	4788	
103	1.6	3 1/4	5.9	16.6	0.35	7.2	14.7	0.49	7.0	0.43	4.7	0.35				C-31568		3
104	4.5	3 3/4	6.2	18.1	0.34	5.9	19.2	0.31								C-31570		

Note 1. 6.3 sack equivalent fly ash mix has 503 lb. of cement and 111 lb. of fly ash/yd^3. Percent of cement reflects combined cement and fly ash.
Note 2. 7.0 sack equivalent fly ash mix has 559 lb. of cement and 124 lb. of fly ash/yd^3. Percent of cement reflects combined cement and fly ash.
Note 3. Tests performed on Morse Bros. 7.0 sack cement/yd^3 mix. No State mix design Lab No.
Note 4. CERL/K-V seemed to produce erratic results on hot days.
Note 5. This mix uses crushed coarse aggregate from source 5-4-1 and sand from source 26-100-1.
Note 6. This mix uses crushed coarse aggregate from source 5-4-1 but has 7.0 sacks of cement/cy^3.
Note 7. This mix uses crushed coarse aggregate from source 26-100-1 and the mix design was made by Northwest Testing Lab.

TABLE 3

Water-cement ratio versus strength for various mixes.

Mix Description		Statistical Data			
		Batched	Titration	Microwave	Analyzers
Class 3300 - 1½", 6 sk.	Y	5371.4	4397.6	5206.0	4989.1
Ideal Type I cement	Slope	-2156.79	-53.26	-1857.81	-1388.67
6 oz. MBAE - 10/yd^3	C	-0.13	-0.02	-0.55	-0.76
Source 26-100-1	N	18	18	9	8
Class 4000 - 3/4", 7 sk.	Y		9293.1		9363.2
Ideal Type III cement	Slope		-6126.36		-6190.72
2.8 oz. Pozz/yd^3	C		-0.63		-0.85
Source 26-100-1	N		13		7
Class 4500 - 1½", 7.2 sk.	Y	1990.0	6042.3		
Ideal Type I cement	Slope	6138.10	-3316.07		
7¼ oz. MBAE - 10/yd^3	C	0.35	-0.70		
Source 26-100-1	N	5	5		
Class 5000 - 3/4", 7½ sk.	Y	7866.6	3687.4	9558.2	6770.9
Oregon Portland Type I cement	Slope	-5951.22	3252.41	-9725.00	-2321.18
7½ oz. MBAE - 10/yd^3	C	-0.51	0.63	-0.88	-0.55
Source 26-2-1	N	9	7	3	6
Class 3300 - 3/4", 6.3 sk.	Y	6768.5	4039.3	7698.8	
Any cement	Slope	-4198.88	1155.40	-6108.55	
6.3 oz. MBAE - 10/yd^3	C	-0.11	0.18	-0.54	
Any source	N	20	12	12	
Class 3300 - 3/4", 6.3 sk.	Y	6868.40	2477.11	5319.55	-864.00
Any Type I cement	Slope	-4331.64	3364.86	-916.12	9150.00
6.3 oz. MBAE - 10/yd^3	C	-0.11	0.78	-0.11	0.65
Any source	N	12	5	5	3
Class 4000 - 3/4", 7 sk.	Y	3313.9	8136.0	4133.1	8429.3
Any cement	Slope	4260.87	-4570.58	3699.35	-4773.44
Pozz. or MBAE - 10	C	0.28	-0.33	0.17	-0.41
Any source	N	10	21	6	11

Y = Y intercept

C = correlation coefficient

N = number of tests

TABLE 4

Recovered water and cement content in terms of as batched for all tests with results by titration and microwave.

Includes fly ash mixes.

Test No.	Water Titration	Water Micro.	Cement Titration	Test No.	Water Titration	Water Micro.	Cement Titration
2	1.19	1.04	0.97	50	0.95	1.01	0.99
3	1.11	0.98	1.07	51	1.10	0.79	0.96
4	1.03	0.67	N.E.P.*	55	0.94	0.81	0.90
7	1.07	0.93	N.E.P.	56	1.00	0.81	0.90
8	1.18	1.06	0.91	59	1.19	1.02	0.84
10	1.00	0.92	N.E.P.	62	0.96	0.83	0.81
11	0.97	0.82	0.99	63	1.19	0.69	0.82
13	1.10	0.96	N.E.P.	65	0.92	0.93	1.00
14	0.94	1.07	0.89	68	1.22	1.14	0.85
15	1.01	0.87	0.99	69	1.29	1.24	0.91
16	1.01	1.12	1.22	73	1.25	1.04	0.56
17	0.86	0.96	0.85	74	1.18	1.19	1.08
18	0.82	0.83	0.84	77	1.31	0.98	0.94
19	1.08	1.15	1.01	80	1.18	0.93	0.86
20	0.78	0.90	0.89	82	1.26	0.93	0.85
21	0.83	0.80	N.E.P.	87	1.21	0.95	0.99
24	0.84	0.84	0.82	88	1.12	1.01	0.95
26	0.88	0.79	0.87	90	1.14	1.18	1.06
27	0.89	0.96	0.89	92	1.18	1.15	1.06
30	0.89	0.87	N.E.P.	94	0.95	0.90	0.97
39	1.11	0.65	0.83	95	1.05	0.89	0.98
41	1.00	0.95	0.63	97	1.00	0.85	0.80
42	1.03	1.12	0.84	100	0.97	0.84	1.07
46	1.00	0.97	0.74	103	1.23	0.97	0.89

* No end point.

	Water Titration	Water Micro.	Cement Titration
No.	48	48	42
Std. dev.	0.137	0.138	0.118
Mean	1.050	0.946	0.910
Variance	0.0184	0.0186	0.0135
High	1.31	1.24	1.22
Low	0.78	0.65	0.56

TABLE 5

Recovered water and cement content in terms of as batched for all tests with results by titration and microwave.

Test numbers for all tests excluding fly ash mixes.

(Refer to Table 4 for test data.)

2	15	41	69	92
3	17	42	73	94
4	18	46	74	95
7	19	55	77	97
8	20	56	80	100
10	24	59	82	103
11	26	62	87	
13	30	65	88	
14	39	68	90	

Statistical Data

	Water		Cement
	Titration	Microwave	Titration
No.	42	42	37
Std. dev.	0.137	0.135	0.112
Mean	1.058	0.953	0.901
Variance	0.0184	0.0177	0.0122
High	1.31	1.24	1.08
Low	0.78	0.67	0.56

Test numbers for mixes containing fly ash.

16	27	51
21	50	63

Statistical Data

	Water		Cement
	Titration	Microwave	Titration
No.	6	6	5
Std. dev.	0.1338	0.1613	0.1514
Mean	0.995	0.895	0.976
Variance	0.0149	0.0217	0.0183
High	1.19	1.12	1.22
Low	0.83	0.69	0.82