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CSA CEMENT TESTING PROGRAMME PHASE III

by

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MINERAL PROCESSING DIVISION

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Mines Branch Investigation Report IR 73-39

CSA CEMENT TESTING PROGRAMME

PHASE III

by

G. G. Carette*

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SUMMARY

This report presents the results of Phase III of the Co-operative Cement Testing Programme sponsored by the CSA Committee on Hydraulic cements. The results of tests for the six samples distributed during this phase are reported and analyzed statistically. The over-all trends of the analyses are found to be very similar to those observed in the two previous phases. The physical tests for fineness by screening on a 200-mesh screen and soundness by autoclave expansion and the chemical determination of the insoluble residue produced some large and inconsistent variations in results which may not be suitable for interlaboratory studies. The reproducibility of the compressive strength results is relatively poor and could probably be improved by the elimination of some evident systematic errors inherent to some laboratories.

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INTRODUCTION

The Mines Branch is continuing to act as an impartial center in co-ordinating the cement testing programme originated by the Subcommittee on Physical Requirements and Test Methods of the CSA Committee on Hydraulic Cements.

The programme was designed in 1960 by the committee as a means for the cement testing laboratories across Canada to evaluate their testing procedures and techniques.

The first phase covered tests on single identical samples from five different cements distributed over a period of 18 months to 27 participating laboratories. It was completed in December 1962 and reported in Mines Branch Investigation Report IR 62-102 (1).

The second phase covered tests on double identical samples from another five cements distributed over a period of three years (1962-1964). The results of that phase were reported in Mines Branch Investigation report IR 66-74 in September 1966 (2).

This report presents results of Phase III of the cement testing programme in which 6 samples* were distributed over about three years (1968-1970). The test results were forwarded to the Mines Branch for processing and analyzing. The summary of test results and the preliminary statistical analyses, including a new laboratory rating system, have already been reported to the participants with each sample. The last four samples distributed in this phase also served in a parallel investigation undertaken to determine the effect of sand variations on the compressive strength of mortar. The results of this particular investigation were reported in Mines Branch investigation report IR 72-21 in May 1972 (3).

*The six samples were numbered from 16 to 21.

PARTICIPATING LABORATORIES

The participants of Phase III were as follows: 22 laboratories of cement plants across Canada, two commercial testing laboratories, two laboratories of government corporations, two provincial department laboratories, one federal department laboratory and one municipal laboratory - a total of 30 laboratories, listed in Appendix A. Most of the laboratories tested all the test samples but some of them failed to do all or some of the tests for any one sample. The maximum and minimum number of participants taking part in any individual test of any of the six samples were 29 and 23, respectively.

The anonymity of the participants was preserved by the use of a code number for each laboratory. A summary report, including statistical analyses and individual laboratory ratings, was sent to the participants after compilation of the results for each sample; this enabled each laboratory to evaluate periodically the accuracy of its own results.

TYPE OF TESTS AND TEST METHODS

Each participating laboratory was asked to do the following physical and chemical tests according to instructions prepared by W.J. Prout, Member, CSA Co-ordination Subcommittee, Committee on Hydraulic Cements.

Physical Tests - General

Normal Consistency: a) amount of water as weight, per cent of dry cement;
b) rod penetration, mm.

Time of Setting: Vicat test, initial and final set, hr and min.

Fineness: a) residue retained on 200-mesh sieve, per cent;
b) air permeability test (Blaine), cm^2 per g.

Soundness: autoclave expansion, per cent.

Physical Tests - Mortar Strength

Compressive Strength at 3, 7, and 28 days, psi.

Water Content, per cent.

Flow of Mortar, per cent.

Chemical Tests

Determination of the following constituents, in per cent:

Loss on ignition (LOI)

Insoluble residue

Sulphur trioxide (SO_3)

Ferric oxide (Fe_2O_3)

Aluminum oxide (Al_2O_3)

Magnesium oxide (MgO)

The test methods to be followed were those of the CSA Standard Specification for Portland Cements A5-1961 including revisions to 1967. The only exception was the Air Permeability test, for which the ASTM Standard Test Method C204-55 was to be used.

PREPARATION AND DISTRIBUTION OF TEST SAMPLES

Cement test samples were prepared and distributed among participating laboratories every six months between March 1968 and September 1970. For each distribution, a 6-bag sample of cement was obtained from the current production of a cement mill chosen at random from the participating companies.

The following cement companies are credited with supplying the required amounts of cement:

1. British Columbia Cement Co. Ltd., Mill Bay, B.C.
2. Canada Cement Lafarge Ltd., St. Constant, P.Q.
3. Canada Cement Lafarge Ltd., Edmonton, Alta.
4. Inland Cement Industries Ltd., Edmonton, Alta.
5. Lake Ontario Portland Cement Co. Ltd., Picton, Ont.
6. St. Lawrence Cement Co. Ltd., Clarkson, Ont.

Each 6-bag sample was mixed dry for 15 minutes in an Ehrsam Tumbler Mixer, dumped into tubs, and riffled into 32 samples (12 to 16 lb each). One of the samples was split into 32 smaller samples for chemical analyses.

The larger test samples were packed in plastic bags which in turn were placed in paper bags. The smaller samples were placed in 2-oz glass bottles or in small sealed plastic bags. The two samples were shipped to the participating laboratories with the testing instructions.

TEST RESULTS

The test results were returned by the participants to this laboratory within four months after the sample distribution.

The results are compiled in Tables 1 to 18 of Appendix B of this report. Statistical analyses of these results were in accordance with standard statistical methods. The maximum and minimum values, average, standard deviation, and coefficient of variation are shown for each set of test results in Tables 19 to 24 of the same Appendix.

The variations in the test results obtained in the most recent and in the two previous phases of this programme are compared in Table 1. The coefficients of variation for all samples of each phase were averaged and are given for each test.

TABLE 1
Comparison of the Coefficients of Variation
 for Phases I, II, and III

Tests	Coeff. of Variation, % (aver.)		
	Phase I	Phase II	Phase III
<u>General</u>			
Normal Consistency - W/c, %	3.4	2.7	2.1
- Rod Pen., in.	7.3	6.6	7.4
Vicat Setting Time - Initial, hr:min	13.0	13.4	13.6
- Final, hr:min	13.8	14.0	13.6
Fineness - Retained on 200 M, % ₂	-	-	-
- Blaine, cm ² /g	3.0	2.1	1.8
Soundness- Expansion, %	-	-	-
<u>Compressive Strength of Mortar</u>			
3-Day, psi	8.7	7.8	9.4
7-Day, psi	7.0	6.4	8.0
28-Day, psi	6.6	6.1	7.4
Water Content, %	3.8	3.3	4.1
<u>Chemical</u>			
Loss on Ignition, %	10.4	12.6	8.2
Insoluble, %	38.0	36.1	26.6
SO ₃ , %	3.6	4.5	3.3
Fe ₂ O ₃ , %	4.6	4.0	2.5
Al ₂ O ₃ , %	4.4	7.1	5.8
MgO, %	6.6	12.6	10.1

DISCUSSION OF TEST RESULTS

It can readily be observed that each phase of the programme presents the same over-all trends in variations. As for the most recent phase, the reproducibility of the chemical tests seems slightly better than that for Phase II but that of the compressive strength tests of mortar seems worse. For the other physical tests (except 200-mesh fineness and soundness for which average values were not computed), the coefficients of variation are much the same as for the preceding phase (Table 1).

Physical Tests - General

As observed for previous samples, the reproducibility for the Vicat test is again relatively poor with coefficients of variation between 9.6 and 18.2 per cent for the initial set and between 11.9 and 16.3 per cent for the final set (Table 2). Two other physical tests (general) show excessively high coefficients of variation, these being the soundness and the 200-mesh fineness tests. However, in these two cases, particularly for the soundness test, the absolute value for the average of all laboratories is usually very small, sometimes in the same order as the inherent variations of the test, so the coefficient of variation is meaningless. The soundness test results for sample 17, for example, show an average value of 0.0004 per cent for the expansion which, of course, would lead to an unreal coefficient of variation. The order of results of these two tests also varies considerably in proportion between cements and has a significant effect on the coefficient of variation. The standard deviation, although not providing any absolute value for the magnitude of variation, might be more representative in analyzing the interlaboratory variations in these cases.

TABLE 2

Coefficients of Variation for Physical and Chemical Tests of Phase III

Tests	Coeff. of Variation (%) for Sample No.					
	16	17	18	19	20	21
<u>Physical-General</u>						
Normal Consistency - W/c, %	2.5	2.4	2.6	2.0	1.7	1.7
- Rod Pen., in	6.3	7.6	7.2	9.5	6.7	7.2
Vicat Setting Time - Initial, hr: min	9.6	11.1	10.6	17.8	14.6	18.2
- Final, hr: min	11.9	15.8	10.3	14.3	13.1	16.3
Fineness - Retained on 200 Mesh %	30.6	26.5	32.5	45.9	24.5	22.2
- Blaine, cm ² /g	2.1	2.3	1.6	2.2	1.6	1.2
Soundness-Expansion, %	25.2	--*	27.7	35.0	31.9	26.3
<u>Physical - Compressive Strength</u>						
3-Day, psi	8.3	11.2	8.4	9.4	10.2	8.9
7-Day, psi	7.3	8.9	6.9	7.5	9.4	7.8
28-Day, psi	5.6	8.8	5.8	7.5	9.9	6.8
Water Content, %	3.9	4.1	4.8	4.0	4.1	3.7
<u>Chemical Analysis</u>						
Loss on Ignition %	9.4	8.3	8.6	10.7	6.7	5.4
Insoluble, %	15.0	25.0	18.9	38.4	35.6	26.4
SO ₃ , %	2.3	4.3	3.2	2.5	4.7	3.1
Fe ₂ O ₃ , %	3.2	2.7	2.3	3.2	1.8	1.7
Al ₂ O ₃ , %	4.9	8.9	6.9	4.9	4.1	4.9
MgO, %	9.3	15.1	8.6	5.8	12.0	9.8

*Not computed as discussed in text.

Physical Tests - Mortar Strength

The coefficients of variation for the compressive strength of mortar were between 5.6 per cent for the 28-day test on Sample 16 and 11.2 per cent for the 3-day test on Sample 17 (Table 2). The average values for the whole phase were 9.4, 8.0 and 7.4 per cent for the 3-, 7-, and 28-day tests (Table 1). These values are considered a little high and probably could be decreased by eliminating the systematic error of a few laboratories. Figure 1 shows a scatter diagram for the 28-day compressive strength, the over-all average

value for three of the six samples of the phase being plotted against the average for the other three, this for each of the laboratories. Similar diagrams, although not included in this report, were also made using different plotting combinations and all of them showed that certain laboratories are associated with a constant large deviation in their results, which greatly contributes to the relatively high interlaboratory variations observed for the compressive strength test.

Chemical Tests

The statistical analyses of chemical test results, as shown in Appendix B of this report, cover all data received. Some of the participants, however, have reported using other than CSA methods; after asking each participant to list the chemical test methods used for this phase, it was found that out of a total of 970 tests performed, 160 (16.5 per cent) were with methods different from CSA, these being mainly ASTM (6.8 per cent) and EDTA* (7.2 per cent) methods. For the loss on ignition, the insoluble, and the sulphur trioxide tests, CSA methods were followed in most cases whereas they were used for about 75 per cent for the ferric, aluminum, and magnesium oxide determinations. For magnesium oxide, in particular, over 25 per cent of the determinations were made by EDTA methods.

Because this programme is primarily concerned with the evaluation of CSA methods the results obtained with other methods, except ASTM, were not included with the over-all data for new statistical analyses. The ASTM methods were retained because of their similarity with CSA and particularly to minimize the reduction in the size of the data for considerations of statistical order. The new computed statistical parameters are shown in

*Diaminoethane tetra acetate reagent.

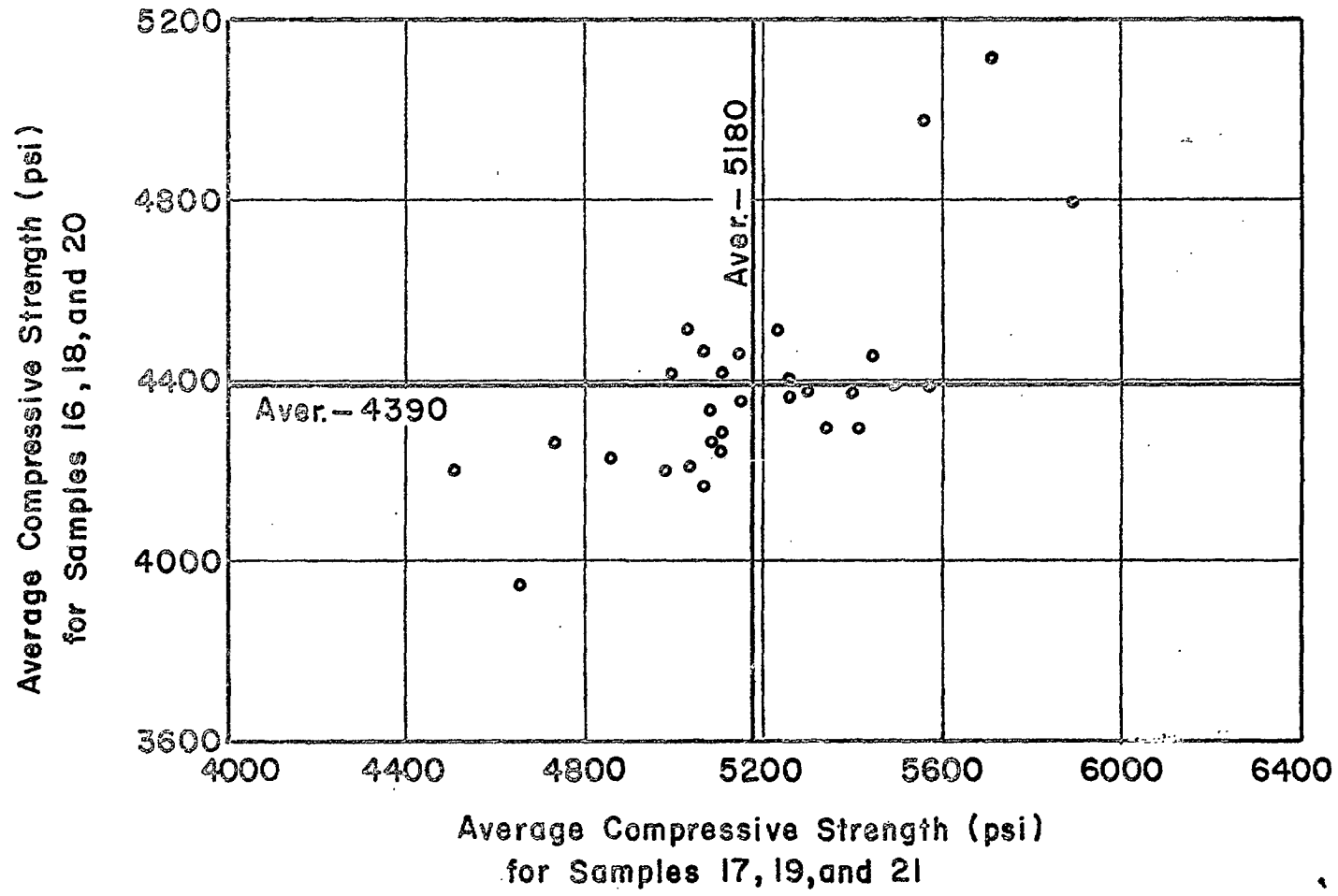


Fig. 1 — Scatter Diagram for 28-Day Compressive Strength Test Results

Tables 3 and 4 together with the ones previously computed for all tests. There is no appreciable change in the coefficients of variation, except for magnesium oxide determinations which, in spite of a significant reduction in the data, show lower values for these coefficients. The reproducibility of this last test remains, however, relatively poor in that the coefficient of variation is between 5.9 per cent for Sample 19 and 14.5 per cent for Sample 17. The reproducibility of the results for the sulphur trioxide and the ferric oxide tests was good with all coefficients of variations under 5 per cent; these were between 4.1 and 8.9 per cent for the aluminum oxide. The loss on ignition and, particularly, the insoluble determinations varied widely between laboratories. For this last test, a nearly constant standard deviation, independently of the level of the insoluble content, is found to cause non-uniform coefficients of variation for different samples.

Laboratory Ratings

A method of laboratory rating was initiated in this phase in order to enable each laboratory to readily know its over-all rating. Individual ratings were computed for physical and chemical tests separately and were reported to the participants after each sample. The procedure used in calculating these ratings and the ratings themselves are given in Appendix C.

TABLE 3

Statistical Analyses of Chemical Test Results - Phase III

CSA** vs All Test Methods

Test Methods	N*		Average, %		Standard Deviation %		Coefficient of Variation, %	
	CSA	ALL	CSA	ALL	CSA	ALL	CSA	ALL
<u>Sample No. 16</u>								
LOI	28	28	1.59	1.59	0.15	0.15	9.4	9.4
Insoluble	27	28	0.42	0.42	0.06	0.06	15.0	15.0
SO ₃	28	28	2.24	2.24	0.05	0.05	2.3	2.3
Fe ₂ O ₃	24	28	2.15	2.15	0.07	0.07	3.4	3.2
Al ₂ O ₃	24	28	4.55	4.53	0.22	0.22	4.8	4.9
MgO	20	28	2.97	2.95	0.29	0.27	9.8	9.3
<u>Sample No. 17</u>								
LOI	28	28	1.47	1.47	0.12	0.12	8.3	8.3
Insoluble	27	28	0.18	0.18	0.05	0.05	25.4	25.0
SO ₃	28	28	2.09	2.09	0.09	0.09	4.3	4.3
Fe ₃ O ₃	24	28	2.96	2.97	0.07	0.08	2.3	2.7
Al ₂ O ₃	24	28	4.46	4.43	0.39	0.39	8.8	8.9
MgO	21	28	1.47	1.52	0.21	0.23	14.5	15.1
<u>Sample No. 18</u>								
LOI	27	27	1.19	1.19	0.10	0.10	8.6	8.6
Insoluble	26	27	0.35	0.35	0.06	0.07	18.6	18.9
SO ₃	27	27	2.77	2.77	0.09	0.09	3.2	3.2
Fe ₂ O ₃	22	27	2.14	2.14	0.05	0.05	2.3	2.3
Al ₂ O ₃	22	27	5.87	5.83	0.42	0.40	7.1	6.9
MgO	17	27	2.81	2.83	0.21	0.24	7.3	8.6

TABLE 3 (cont'd)

Test Methods	N*		Average, %		Standard Deviation, %		Coefficient of Variation, %	
	CSA	ALL	CSA	ALL	CSA	ALL	CSA	ALL
<u>Sample No. 19</u>								
LOI	26	26	1.65	1.65	0.18	0.18	10.7	10.7
Insoluble	25	26	0.15	0.15	0.06	0.06	38.0	38.4
SO ₃	27	27	1.93	1.93	0.05	0.05	2.5	2.5
Fe ₂ O ₃	22	27	1.86	1.86	0.06	0.06	3.4	3.2
Al ₂ O ₃	22	27	4.76	4.73	0.22	0.23	4.6	4.9
MgO	18	27	3.47	3.52	0.20	0.21	5.9	5.8
<u>Sample No. 20</u>								
LOI	26	26	1.20	1.20	0.08	0.08	6.7	6.7
Insoluble	25	26	0.23	0.23	0.08	0.08	36.4	35.6
SO ₃	26	26	2.68	2.68	0.13	0.13	4.7	4.7
Fe ₂ O ₃	24	26	2.35	2.34	0.04	0.04	1.8	1.8
Al ₂ O ₃	24	26	5.75	5.73	0.23	0.23	4.0	4.1
MgO	21	26	2.10	2.12	0.19	0.26	9.2	12.0
<u>Sample No. 21</u>								
LOI	26	26	1.60	1.60	0.09	0.09	5.4	5.4
Insoluble	25	26	0.32	0.32	0.08	0.08	26.2	26.4
SO ₃	26	26	2.20	2.20	0.07	0.07	3.1	3.1
Fe ₂ O ₃	24	26	2.86	2.86	0.04	0.05	1.4	1.7
Al ₂ O ₃	24	26	5.47	5.47	0.28	0.27	5.0	4.9
MgO	21	26	1.54	1.55	0.15	0.15	10.0	9.8

* N - number of tests

** Also includes ASTM methods

TABLE 4
Average Coefficients of Variation for Chemical Tests.
Phase III (CSA vs All Test Methods)

Chemical Tests	N*		Coefficient of Variation, %	
	CSA** methods	All methods	CSA ** methods	All methods
Loss on ignition	161	161	8.2	8.2
Insoluble	155	161	26.6	26.6
Sulphur trioxide	162	162	3.3	3.3
Ferric oxide	140	162	2.4	2.5
Alumina	140	162	5.7	5.8
Magnesia	118	162	9.4	10.1

* Number of results

** Also includes ASTM methods

CONCLUSIONS

1. The over-all trends of the analyses of test results for Phase III are very similar to those for the previous two phases; in this phase, however, the reproducibility for the chemical tests is slightly improved, whereas, for the compressive strength tests, it is worse.
2. The fineness (per cent retained on 200 mesh), the soundness (autoclave expansion), and the insoluble residue results have extremely high and inconsistent coefficients of variation. These three tests, consequently, are not suitable for the evaluation of individual laboratory procedures in interlaboratory studies.
3. The relatively high magnitude of variation observed in some tests such as the compressive strength is caused by systematic deviation in test procedures of some of the laboratories.

REFERENCES

1. N.G. Zoldners and V.M. Malhotra; CSA Cement Testing Programme - Phase I; Mines Branch Investigation Report IR 62-102, December 1962.
2. N.G. Zoldners and V.M. Malhotra; CSA Cement Testing Programme - Phase II; Mines Branch Investigation Report IR 66-74, September 1966.
3. N.G. Zoldners and G.G. Carrette; Effect of Variations in Standard Sand on Compressive Strength of Mortar Cubes; Mines Branch Investigation Report IR 72-21, May 1972.

APPENDIX A

Participating Laboratories and Organizations

<u>Testing Laboratory/Organization</u>	<u>Location</u>
Newfoundland	
North Star Cement Limited.....	Corner Brook
New Brunswick	
Canada Cement Lafarge Limited.....	Havelock
Quebec	
Canada Cement Lafarge Limited.....	Montreal
Canada Cement Lafarge Limited.....	Hull
Canada Cement Lafarge Limited.....	St. Constant
Ciment Independant Inc.....	Joliette
Ciment Quebec Inc.....	St. Basile
City of Montreal.....	Montreal
Industrial & Commercial Laboratories.....	Montreal
Ministère de la Voirie.....	Quebec
Miron Company Ltd.....	Montreal
St. Lawrence Cement Company Ltd.....	Villeneuve
Ontario	
Canada Cement Lafarge Limited.....	Belleville
Canada Cement Lafarge Limited.....	Woodstock
Department of Public Works.....	Ottawa
Hydro-Electric Power commission of Ontario.....	Toronto
Lake Ontario Portland Cement Limited.....	Picton
Ontario Department of Highways.....	Toronto
St. Lawrence Cement Company Ltd.....	Clarkson
St. Mary's Cement Co. Limited.....	St. Mary's
St. Mary's Cement Co. Limited.....	Bowmanville
Manitoba	
Canada Cement Lafarge Limited.....	Fort Whyte
National Testing Laboratories Limited.....	Winnipeg
Saskatchewan	
Department of Agriculture.....	Saskatoon
Inland Cement Industries Limited.....	Regina
Alberta	
Canada Cement Lafarge Limited.....	Edmonton
Canada Cement Lafarge Limited.....	Exshaw
Inland Cement Industries Limited.....	Edmonton
British Columbia	
Canada Cement Lafarge Limited.....	Richmond
British Columbia Cement Co. Limited.....	Mill Bay

APPENDIX B

Compilation of Test Results

Tables 1 to 3	(Test Results for Sample 16)
4 to 6	(Test Results for Sample 17)
7 to 9	(Test Results for Sample 18)
10 to 12	(Test Results for Sample 19)
13 to 15	(Test Results for Sample 20)
16 to 18	(Test Results for Sample 21)
19	(Summary of Statistical Analyses for Sample 16)
20	(Summary of Statistical Analyses for Sample 17)
21	(Summary of Statistical Analyses for Sample 18)
22	(Summary of Statistical Analyses for Sample 19)
23	(Summary of Statistical Analyses for Sample 20)
24	(Summary of Statistical Analyses for Sample 21)

TABLE 1

Physical Tests - General

Test Sample No. 16

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	24.0	9	2:45	5:00	4.9	3110	0.05
B	24.0	9.5	2:50	4:20	5.6	3035	0.05
C	24.0	9	2:45	4:55	5.8	3120	0.05
D	24.2	10	2:45	3:50	6.0	3208	0.03
E	23.5	9	2:35	4:20	4.7	3110	0.03
F	23.5	10.5	2:55	4:30	6.3	3030	0.066
G	23.5	10	2:40	4:30	4.7	3010	0.04
H	23.0	9	2:40	4:05	6.0	3080	0.05
I	25.9	10	3:00	5:30	6.1	-	0.04
J	25.0	11	3:00	5:15	6.0	3010	0.06
K	23.2	9	2:30	4:25	5.7	3060	0.06
L	23.6	10	2:40	4:10	6.2	3191	0.044
M	23.5	10	2:25	4:20	4.2	3040	0.06
N	24.0	11	2:15	-	4.5	3060	0.04
O	24.0	9.5	2:55	4:30	4.6	3030	0.034
P	24.0	9	2:45	4:45	4.8	3070	0.05
Q	24.2	11	2:46	4:16	6.2	3159	0.06
S	23.5	10	2:40	4:05	2.2	2948	0.06
T	24.0	10	2:37	4:23	4.8	3168	0.057
U	23.4	10	2:55	-	4.5	3070	0.04
V	24.5	9.5	2:50	3:40	3.5	3050	0.06
W	23.4	9.5	2:20	3:45	5.8	3010	0.056
X	23.5	10	2:37	4:27	4.5	3030	0.06
Y	24.0	10	3:00	5:25	6.1	3021	0.06
Z	23.6	-	2:50	4:50	3.4	3130	0.06
XX	24.0	10.5	2:00	4:45	8.0	-	0.04
ZZ	24.0	10	2:25	3:25	11.1	3059	0.05
YY	25.0	-	3:14	3:45	9.0	2990	0.07
VV	23.6	10	3:00	5:00	5.6	3122	0.016
AA	-	-	-	-	-	-	-

* W/C = Water-Cement Ratio.

TABLE 2

Physical Tests - Mortar Strength

Test Sample No. 16

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	50.0	105	2780	3320	4520
B	-	102	3075	3735	4750
C	49.3	108	2800	3400	4380
D	48.6	106	2090	3100	4130
E	48.0	110	2800	3480	4460
F	47.3	113	3035	3685	4415
G	47.3	107	2850	3520	4560
H	47.0	111	2860	3390	4660
I	51.9	100	2375	2950	4700
J	47.2	109	2915	3505	4220
K	47.5	103	2710	3350	4390
L	47.3	108	3092	4108	5225
M	47.5	107	2870	3560	4510
N	47.0	111	2580	3340	4250
O	46.5	110	2917	3383	4458
P	47.0	103	2920	3670	4800
Q	46.7	108	2850	3217	4221
S	46.0	105	2920	3987	4575
T	47.3	101	3070	3670	4825
U	45.5	107	2950	3580	4480
V	54.0	110	2990	3820	5060
W	47.3	104	2783	3383	4642
X	46.0	103	3033	3741	4850
Y	47.0	109	2890	3640	4465
Z	47.0	107	3260	3860	4870
XX	50.0	-	-	3525	4350
ZZ	-	104	2585	3485	4460
YY	-	-	-	-	-
VV	47.0	109	2670	3275	4454
AA	-	-	-	-	-

TABLE 3

Chemical Analysis

Test Sample No. 16

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.65	0.44	2.28	2.12	4.44	3.13
B	1.70	0.40	2.20	2.15	4.30	2.80
C	1.54	0.28	2.26	2.12	4.25	3.07
D	1.66	0.44	2.26	2.12	4.76	2.10
E	1.52	0.37	2.30	2.14	4.38	2.92
F	-	-	-	-	-	-
G	1.52	0.47	2.23	2.15	4.51	2.80
H	1.61	0.39	2.12	2.19	4.58	2.98
I	1.29	0.47	2.27	2.23	5.33	3.02
J	1.69	0.37	2.20	2.15	4.49	3.20
K	1.59	0.41	2.25	2.06	4.30	2.81
L	1.54	0.40	2.25	2.18	4.57	3.18
M	1.58	0.38	2.23	2.12	4.46	3.11
N	1.68	0.40	2.27	2.20	4.42	3.09
O	1.55	0.39	2.28	1.96	4.76	2.82
P	1.55	0.35	2.29	2.16	4.42	2.92
Q	1.53	0.46	2.32	2.11	4.53	2.90
S	1.58	0.41	2.28	2.11	4.43	2.68
T	1.52	0.56	2.22	2.17	4.61	2.81
U	1.66	0.42	2.15	2.14	4.30	2.92
V	1.50	0.44	2.21	2.12	4.33	3.06
W	1.51	0.43	2.26	2.25	4.64	2.95
X	2.21	0.37	2.21	2.26	4.43	2.92
Y	1.74	0.35	2.32	2.14	4.70	2.68
Z	1.62	0.42	2.19	2.13	4.43	2.50
XX	1.49	0.50	2.24	2.12	4.90	3.17
ZZ	1.50	0.58	2.21	2.35	4.45	3.58
YY	1.63	0.51	2.13	2.11	4.64	2.98
VV	1.49	0.43	2.20	2.16	4.43	3.36
AA	-	-	-	-	-	-

TABLE 4

Physical Tests - General

Test Sample No. 17

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	24.0	10	2:45	5:55	1.9	3490	+ .006
B	24.0	9	1:54	4:05	1.1	3475	+ .006
C	23.6	11	2:20	4:50	-	3570	+ .008
D	25.4	11	2:55	3:50	2.0	3630	+ .03
E	23.5	10	2:15	4:05	1.2	3450	.00
F	24.5	11	2:45	4:15	1.5	3490	+ .004
G	24.5	9.5	2:35	5:00	1.5	3470	- .01
H	23.9	10	2:30	3:10	1.2	3403	- .02
I	26.2	9	3:00	5:20	1.4	-	+ .01
J	25.0	9	2:20	3:20	1.8	3440	+ .002
K	24.4	11	2:25	4:15	1.7	3380	.00
L	24.0	-	2:30	4:15	1.3	3408	+ .014
M	24.0	9	2:10	4:00	1.4	3460	- .01
N	25.0	11	2:20	-	1.0	3460	.00
O	24.0	9.5	2:35	4:15	1.1	3600	- .005
P	24.4	9	2:35	4:45	1.4	3470	- .01
Q	24.2	9	2:16	4:10	2.0	3530	-
S	23.7	9	2:25	3:50	1.3	3502	- .01
T	24.5	10.5	2:40	3:47	1.0	3543	- .016
U	24.0	9	2:20	-	1.8	3490	- .01
V	24.6	10	2:15	4:10	1.0	3525	.00
W	24.2	9	2:20	3:50	2.1	3385	.00
X	23.5	10	2:18	4:05	1.4	3404	-0.01
Y	23.8	10	2:35	5:10	1.0	3502	- .009
Z	24.0	-	2:45	5:00	0.8	3470	.00
XX	24.6	10	-	-	-	3441	+ .01
ZZ	24.0	10	2:25	3:25	2.0	3211	+ .03
YY	-	-	3:15	5:30	2.0	3400	+ .016
VV	24.2	10	2:40	4:55	1.9	3480	- .014
AA	-	-	-	-	-	-	-

* W/C = Water-Cement Ratio.

TABLE 5

Physical Tests - Mortar Strength

Test Sample No. 17

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	50.0	112	2740	3540	5000
B	-	109	3085	3875	5060
C	45.3	104	3250	4020	5400
D	49.3	109	2067	3167	4125
E	48.0	107	2620	3490	4650
F	45.9	105	2980	3690	5000
G	46.6	110	3130	3950	5050
H	46.0	113	3330	4120	5560
I	-	105	2660	3600	4915
J	47.3	-	3075	3760	5015
K	48.5	113	2590	3400	4780
L	49.3	114	3242	3967	5642
M	48.0	111	3020	3780	4930
N	48.0	104	2590	3330	4530
O	47.5	109	2750	3500	4650
P	44.6	107	2890	3630	4610
Q	-	-	2671	3462	4687
S	-	-	3037	3694	5000
T	47.3	-	2975	3740	5215
U	-	-	3000	3450	4640
V	53.0	110	2530	3420	4630
W	48.7	105	2875	3667	4954
X	45.0	106.5	3258	3987	5171
Y	46.0	100.5	2890	3450	4730
Z	46.5	105	3310	4300	5720
XX	49.0	-	-	4540	6140
ZZ	-	101	2625	3740	5210
YY	49.0	106	2160	2985	4320
VV	45.5	106	2746	3542	4572
AA	-	-	-	-	-

TABLE 6

Chemical Analysis

Test Sample No. 17

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.54	0.21	2.13	2.92	4.56	1.17
B	1.45	0.20	2.00	2.95	3.90	1.55
C	1.62	0.17	2.22	3.10	3.93	1.68
D	1.66	0.14	2.02	2.96	4.44	1.31
E	1.46	0.15	2.06	2.97	4.25	1.52
F	-	-	-	-	-	-
G	1.39	0.21	2.09	2.89	4.57	1.56
H	1.46	0.15	2.06	2.95	4.28	1.50
I	1.48	0.14	2.08	3.03	5.05	1.61
J	1.58	0.23	2.15	2.76	5.68	1.72
K	1.41	0.20	2.07	2.98	4.22	2.18
L	1.31	0.18	1.98	3.03	5.24	1.72
M	1.48	0.16	2.03	3.00	4.02	1.51
N	1.43	0.17	2.11	2.98	4.42	1.40
O	1.27	0.13	2.03	2.98	4.39	1.32
P	1.41	0.19	2.17	2.93	4.45	1.42
Q	1.59	0.18	2.02	2.98	4.25	1.38
S	1.34	0.14	2.04	2.90	4.36	1.43
T	1.33	0.25	2.13	2.97	4.40	1.21
U	1.52	0.20	2.07	2.95	4.39	1.55
V	1.69	0.19	2.01	2.90	4.61	2.05
W	1.35	0.13	2.09	2.87	4.67	1.38
X	1.50	0.17	2.21	3.08	4.24	1.52
Y	1.34	0.29	2.15	3.16	4.50	1.26
Z	1.51	0.16	2.02	2.92	4.43	1.74
XX	1.35	0.30	2.06	2.86	4.59	1.52
ZZ	1.75	0.10	2.39	3.05	4.05	1.48
YY	1.47	0.21	2.10	3.02	3.85	1.59
VV	1.36	0.20	1.93	2.95	4.23	1.21
AA	-	-	-	-	-	-

TABLE 7

Physical Tests - General

Test Sample No. 18

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	25.0	9.0	2:15	4:35	4.2	3360	0.058
B	25.4	-	2:25	4:10	2.6	3290	0.06
C	25.2	11.0	2:50	5:20	-	3370	0.058
D	25.8	11.0	3:10	4:15	4.4	3278	0.03
E	24.2	9.0	2:20	4:10	3.2	3380	0.06
F	24.5	10.0	2:45	4:50	4.2	3290	0.062
G	24.5	9.5	2:45	4:40	3.3	3350	0.05
H	24.8	10.5	2:30	4:35	2.1	3350	0.07
I	26.9	10.4	2:25	4:20	2.6	-	0.04
J	25.5	10.0	2:00	3:50	3.2	3390	0.07
K	25.2	11.0	2:55	5:00	3.5	3310	0.03
L	24.8	-	2:20	4:25	-	3346	0.05
M	25.0	9.0	2:20	4:10	3.5	3340	0.06
N	-	-	-	-	-	-	-
O	24.8	-	2:40	4:35	2.7	3160	0.045
P	25.2	9.0	2:35	4:35	3.6	3350	0.06
Q	25.1	9.0	2:36	4:37	4.6	3387	0.02
S	25.0	10.0	2:45	4:55	2.5	3370	0.05
T	25.0	9.5	2:28	3:48	3.7	3396	0.065
U	25.5	9.0	2:55	-	3.0	3330	0.04
V	25.0	10.0	2:50	4:00	2.0	3275	0.04
W	24.2	10.0	2:25	3:40	5.8	3257	0.054
X	24.5	10.0	2:20	4:45	3.1	3241	0.07
Y	24.2	9.0	2:45	4:55	2.8	3312	0.03
Z	25.0	-	2:45	5:05	2.3	3280	0.07
XX	25.4	11.0	2:45	5:30	3.0	3345	0.03
ZZ	-	-	-	-	-	-	-
YY	27.0	9.5	3:10	4:50	7.1	3330	0.052
VV	25.1	10.0	2:55	5:00	3.3	3398	0.045
AA	25.1	10.0	2:30	4:00	3.5	3360	0.052

* W/C = Water-Cement Ratio.

TABLE 8

Physical Tests - Mortar Strength

Test Sample No. 18

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	50.0	108.0	2850	3480	4460
B	48.8	103.0	2875	3650	4475
C	50.0	115.0	2880	3540	4333
D	50.9	107.0	2670	3470	4100
E	49.0	107.0	2900	3690	4680
F	48.6	100.0	2755	3435	4355
G	47.3	110.0	3050	3610	4520
H	46.0	102.0	2970	3540	4400
I	52.3	102.0	2200	2940	4550
J	48.0	103.0	3050	3775	4710
K	48.5	110.0	2740	3450	4500
L	51.0	108.5	2825	3700	4775
M	49.5	103.0	2870	3450	4320
N	-	-	-	-	-
O	-	105.0	2850	3500	4375
P	48.5	110.0	2930	3620	4570
Q	48.0	103.0	2894	3433	4296
S	49.0	106.0	2722	3300	4050
T	46.6	101.6	2925	3541	4525
U	48.5	101.0	2800	3300	4100
V	56.0	112.0	2440	3320	4760
W	51.7	105.0	2367	3300	4648
X	48.5	108.5	2846	3563	4445
Y	46.5	102.3	3115	3690	4750
Z	48.5	100.0	2820	3680	4720
XX	51.3	109.4	2650	3760	4680
ZZ	-	-	-	-	-
YY	55.3	106.0	2215	2756	3678
VV	49.0	105.6	2576	3068	4151
AA	48.6	104.0	2980	3533	4485

TABLE 9

Chemical Analysis

Test Sample No. 18

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.24	0.32	2.85	2.10	5.94	2.93
B	1.29	0.33	2.75	2.21	5.30	2.75
C	1.13	0.27	2.90	2.17	5.42	2.90
D	1.38	0.30	2.64	2.08	6.10	2.26
E	1.18	0.33	2.76	2.12	5.74	2.96
F	-	-	-	-	-	-
G	1.14	0.32	2.88	2.19	5.93	2.72
H	1.06	0.43	2.79	2.10	5.88	3.11
I	0.95	0.37	2.84	2.15	6.39	2.68
J	1.25	0.32	2.80	2.09	6.15	3.08
K	1.12	0.39	2.80	2.16	5.76	2.89
L	1.20	0.45	2.68	2.22	5.97	3.12
M	1.12	0.35	2.67	2.10	5.82	2.97
N	-	-	-	-	-	-
O	1.24	0.22	2.78	2.03	6.08	2.57
P	1.13	0.36	2.82	2.16	5.84	2.99
Q	1.20	0.34	2.76	2.12	5.97	2.73
S	1.20	0.39	2.78	2.09	5.85	2.82
T	1.18	0.36	2.75	2.13	5.92	3.01
U	1.23	0.37	2.80	2.17	5.89	2.75
V	1.32	0.35	2.79	2.22	5.80	3.25
W	1.04	0.36	2.81	2.20	6.06	2.65
X	1.23	0.45	2.85	2.16	5.80	2.83
Y	1.05	0.27	2.56	2.16	5.96	2.14
Z	1.28	0.35	2.69	2.17	5.93	2.79
XX	1.32	0.37	2.72	2.08	6.03	2.77
ZZ	-	-	-	-	-	-
YY	1.39	0.53	2.97	2.19	4.11	2.99
VV	1.17	0.24	2.61	2.18	5.85	2.69
AA	1.22	0.30	2.76	2.10	5.90	2.99

TABLE 10

Physical Tests - General

Test Sample No. 19

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	26.5	11	2:00	3:35	0.5	3340	0.44
B	25.6	9.5	2:04	4:43	0.4	3340	0.44
C	24.8	11	3:20	4:45	1.0	3445	-
D	26.0	10	2:55	3:55	1.6	3482	0.19
E	26.0	9.5	2:20	4:10	0.2	3310	0.25
F	25.5	9.5	2:35	3:40	0.8	3270	0.364
G	25.5	6.5	2:10	4:00	0.4	3350	0.25
H	25.8	9.5	2:25	4:25	0.22	3120	0.47
I	27.0	10	2:26	4:35	1.5	-	0.30
J	26.0	-	2:05	3:25	0.8	3280	0.52
K	24.8	9	2:20	4:10	0.6	3360	0.29
L	27.0	10	1:20	3:35	-	3219	0.273
M	25.0	9	1:50	3:40	0.7	3350	0.12
N	26.5	9	2:05	-	0.5	3340	0.47
O	26.0	10	2:35	4:45	0.8	3300	0.415
P	25.7	10	2:25	4:25	0.5	3430	0.38
Q	26.1	10	2:02	4:44	0.8	3348	0.25
S	25.6	10	2:35	5:00	0.47	3330	0.30
T	26.0	11	2:07	3:21	0.51	3377	0.299
U	26.0	10	2:30	-	0.8	3400	0.20
V	26.0	10	2:25	4:10	1.0	3300	0.28
W	25.0	9	2:10	3:20	1.0	3305	0.268
X	25.5	10.5	2:22	4:42	0.66	3298	0.24
Y	25.6	9.5	2:40	5:05	0.5	3370	0.22
Z	26.0	-	3:00	5:30	0.47	3280	0.47
XX	-	-	-	-	-	-	-
ZZ	-	-	-	-	-	-	-
YY	26.6	9.5	3:00	4:45	1.2	3355	0.274
VV	25.6	9.5	2:50	4:30	0.6	3310	0.22
AA	26.0	9.0	2:20	4:00	0.7	3340	0.512

* W/C = Water-Cement Ratio.

TABLE 11

Physical Tests - Mortar Strength

Test Sample No. 19

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	50.0	104	2570	4210	5870
B	48.8	106	2415	3675	4935
C					
D	49.6	-	2615	3413	5052
E	48.5	102	2350	3680	5030
F	49.3	102	2435	3860	5175
G	48.0	102	2740	4240	5740
H	49.0	113	2460	3870	5210
I					
J	48.7	107	2570	4030	5525
K	49.0	101	2340	3640	5150
L	50.0	115	2617	4083	5842
M	49.5	106	2770	4260	5680
N	49.5	110	2220	3830	-
O	47.8	107	2500	3708	5183
P	48.5	109.5	2010	3900	5690
Q	48.5	111	2466	3816	4846
S	49.0	112	2156	3656	5033
T	46.6	104	2490	3970	5440
U	48.5	107	2500	3830	5150
V	53.1	105	2080	3550	6100
W	52.0	110	2346	3992	4975
X	48.5	111	2554	4037	5342
Y	47.5	102	2520	4120	5440
Z	48.0	104	2760	4440	6110
XX	-	-	-	-	-
ZZ	-	-	-	-	-
YY	56.0	100	2073	3060	4500
VV					
AA	48.0	107	2430	3625	5040

TABLE 12

Chemical Analysis

Test Sample No. 19

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.64	0.10	1.92	2.04	4.38	3.77
B	1.68	0.12	1.89	1.90	4.26	3.74
C	2.07	0.15	2.00	1.89	4.39	3.42
D	1.76	0.18	1.86	1.88	4.52	3.62
E	1.66	0.14	1.96	1.83	4.69	3.52
F	1.69	0.09	1.94	1.82	4.63	3.62
G	1.68	0.22	1.91	1.91	4.61	3.58
H	-	-	-	-	-	-
I	1.47	0.16	1.91	1.91	5.29	3.55
J	1.78	0.09	1.93	1.82	5.08	3.70
K	1.60	0.21	1.93	1.87	4.61	3.58
L	1.60	0.17	1.90	1.87	4.64	3.69
M	1.62	0.13	1.84	1.84	4.73	3.58
N	-	-	1.99	1.73	4.73	3.02
O	1.70	0.10	1.99	1.80	4.58	3.32
P	1.63	0.17	2.01	1.92	4.56	3.25
Q	1.78	0.06	1.90	1.81	4.69	3.31
S	1.55	0.10	1.90	1.81	4.65	3.34
T	1.59	0.29	2.00	1.86	4.84	3.48
U	1.69	0.18	1.96	1.94	4.82	3.52
V	1.83	0.14	1.86	1.90	4.67	4.02
W	1.56	0.12	1.88	1.85	5.15	3.39
X	1.69	0.10	1.92	1.83	4.84	3.50
Y	1.57	0.18	2.01	1.88	4.89	3.55
Z	1.63	0.24	1.88	1.81	4.77	3.44
XX	-	-	-	-	-	-
ZZ	-	-	-	-	-	-
YY	1.69	0.25	1.90	1.88	5.06	3.62
VV	1.65	0.18	1.95	1.90	4.68	3.18
AA	0.98	0.07	1.95	1.81	4.85	3.73

TABLE 13

Physical Tests - General

Test Sample No. 20

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	25.0	10.5	1:50	3:30	3.8	3240	0.066
B	24.6	10.5	1:45	2:50	5.4	3110	0.074
C	24.6	9	1:50	4:10	3.8	3259	0.053
D	25.4	10	1:45	2:40	5.2	3252	0.056
E	24.5	10	1:40	3:30	3.9	3150	0.08
F	24.5	10	1:50	3:20	3.1	3310	0.084
G	24.5	9.5	1:40	3:25	4.0	3160	0.05
H	24.0	9	1:40	3:20	2.0	3145	0.09
I	-	-	-	-	-	-	-
J	24.5	-	1:40	3:50	5.6	3210	0.02
K	24.0	10	1:40	3:20	4.3	3240	0.01
L	24.4	10	2:00	3:50	4.3	3194	0.074
M	24.5	9	1:40	3:30	3.6	3140	0.07
N	25.4	9	1:45	-	4.0	3180	-
O	24.8	10.5	2:00	4:05	3.3	3200	0.051
P	24.8	11.	1:55	3:50	3.8	3200	0.08
Q	24.7	11	1:56	4:10	4.4	3240	0.07
S	24.0	9	1:45	2:50	3.2	3254	0.07
T	24.5	-	1:57	2:58	3.4	3335	0.063
U	24.5	10	2:00	-	3.3	3250	0.05
V	25.0	11	2:40	3:20	2.0	3225	0.10
W	24.6	10	1:35	3:00	4.9	3234	0.064
X	25.0	11	1:30	3:15	3.8	3187	0.08
Y	-	-	-	-	-	-	-
Z	25.6	10	2:35	4:00	2.8	3220	0.06
XX	-	-	-	-	-	-	-
ZZ	-	-	-	-	-	-	-
YY	25.0	9.5	2:05	3:00	2.3	3190	0.062
VV	24.4	10	2:00	3:55	4.0	3260	0.04
AA	25.0	10	1:40	3:00	4.4	3170	0.084

* W/C = Water-Cement Ratio.

TABLE 14

Physical Tests - Mortar Strength

Test Sample No. 20

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	48.5	100	2470	3170	4160
B	46.4	103	2935	3575	4300
C	48.6	109	2540	3320	-
D	50.8	112	2805	3538	4371
E	48.5	112	2430	3090	4130
F	48.6	104	2375	2990	3865
G	48.3	105	2470	3250	4280
H	48.0	109	2500	3190	4080
I	-	-	-	-	-
J	48.7	106	2450	3125	3935
K	48.5	112	2330	3030	4160
L	48.0	108	2942	3875	5325
M	48.5	105	2500	3250	4330
N	48.5	107	2560	3170	3900
O	46.6	111	2500	3125	4158
P	48.5	111	2570	3280	4170
Q	48.0	113	2570	3170	4270
S	49.6	103	2024	2893	3850
T	46.6	105.4	2387	2958	3850
U	48.5	111	2480	3250	4140
V	54.7	100	2080	2930	5120
W	52.0	100	2292	2817	3983
X	50.0	103.7	2158	2779	3542
Y	-	-	-	-	-
Z	47.5	104	2750	3590	4800
XX	-	-	-	-	-
ZZ	-	-	-	-	-
YY	54.1	107	1905	2425	3605
VV	49.0	105.6	2249	3014	4104
AA	47.3	108	2394	2894	3727

TABLE 15

Chemical Analysis

Test Sample No.20

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.12	0.20	2.78	2.32	5.78	2.19
B	1.16	0.17	2.68	2.31	6.41	2.72
C	1.32	0.24	2.70	2.27	5.42	2.09
D	1.30	0.18	2.68	2.34	5.86	2.10
E	1.23	0.23	2.74	2.32	5.78	2.06
F	1.20	0.41	2.70	2.39	5.59	2.10
G	1.09	0.23	2.65	2.43	5.83	*1.71
H	1.34	0.22	2.70	2.38	5.72	2.20
I	-	-	-	-	-	-
J	1.20	0.17	2.73	2.37	5.80	2.20
K	1.13	0.28	2.74	2.36	5.64	*2.14
L	1.28	0.20	2.72	2.35	5.89	2.19
M	1.11	0.21	2.64	2.32	5.62	2.35
N	1.28	0.15	2.72	2.37	5.75	2.05
O	1.25	0.22	2.65	2.24	5.82	1.78
P	1.19	0.27	2.75	2.33	5.65	2.05
Q	1.17	0.27	2.62	2.39	5.92	2.07
S	1.10	0.18	2.81	2.37	5.65	2.02
T	1.14	0.38	2.73	2.39	5.87	1.91
U	1.39	0.08	2.70	2.30	5.80	2.24
V	1.26	0.22	2.70	2.35	5.55	2.95
W	1.17	0.21	2.79	2.35	5.74	1.92
X	1.17	0.26	2.73	2.28	5.78	1.97
Y	-	-	-	-	-	-
Z	1.20	0.20	2.60	2.37	5.73	2.04
XX	-	-	-	-	-	-
ZZ	-	-	-	-	-	-
YY	1.14	0.48	2.13	2.34	4.96	1.91
VV	1.11	0.19	2.55	2.38	5.80	1.98
AA	1.18	0.20	2.64	2.33	5.69	2.13

TABLE 16

Physical Tests - General

Test Sample No. 21

Participant	Normal Consistency		Time of Setting, hr:min		Fineness		Soundness
	W/C,* %	Penetration, mm	Vicat		Retained on 200M, %	Blaine, cm ² /g	Autoclave Expansion, %
			Initial	Final			
A	24.5	9.5	1:55	4:00	4.4	3170	0.106
B	24.0	11.0	1:47	4:00	6.4	3030	0.100
C	23.6	9.5	2:15	4:40	4.2	3065	0.080
D	25.0	10.0	2:10	3:30	5.9	3160	0.090
E	24.4	11.0	2:10	4:00	2.3	3050	0.080
F	24.0	9.5	2:05	3:45	3.9	3090	0.122
G	24.5	10.0	1:40	3:30	4.9	3130	0.100
H	23.4	10.5	1:45	3:15	5.0	3090	0.100
I	-	-	-	-	-	-	-
J	24.5	10.0	2:00	4:15	5.6	3120	0.100
K	24.4	11.0	2:05	3:55	2.3	3060	0.070
L	24.5	11.0	1:30	3:05	4.6	3097	0.118
M	25.0	10.0	1:30	3:20	4.5	3070	0.120
N	25.0	9.0	1:40	3:35	4.9	3080	0.080
O	24.0	10.0	2:10	-	4.1	3050	0.107
P	24.6	9.0	1:50	3:45	4.5	3120	0.120
Q	24.2	9.0	1:54	4:01	5.2	3106	-
S	24.2	9.0	1:50	2:34	4.1	3117	0.120
T	24.0	11.0	1:46	2:46	4.3	3182	-0.003
U	24.5	10.0	-	-	4.7	3130	0.090
V	24.6	10.0	1:40	2:25	3.8	3075	0.120
W	24.6	9.0	1:40	3:25	5.4	3106	0.102
X	24.5	10.5	1:55	4:35	5.2	3068	0.110
Y	-	-	-	-	-	-	-
Z	24.6	-	2:10	4:35	3.7	3080	0.130
XX	-	-	-	-	-	-	-
ZZ	-	-	-	-	-	-	-
YY	24.7	9.0	3:15	4:10	2.8	3090	0.095
VV	23.7	10.0	2:25	4:15	4.2	3078	0.085
AA	24.0	10.0	2:00	4:00	3.8	3070	0.106

* W/C = Water-Cement Ratio.

TABLE 17

Physical Tests - Mortar Strength

Test Sample No.21

Participant	Water Content, %	Flow, %	Compressive Strength, psi		
			3-day	7-day	28-day
A	50.7	100	2460	3980	5330
B	49.2	106	2115	3735	5100
C	-	-	-	-	-
D	51.5	105	1925	3096	4365
E	48.5	91	2380	3940	5610
F	49.3	103	2280	3820	4925
G	48.5	101	2680	4260	5520
H	49.0	111	2290	3650	5120
I	-	-	-	-	-
J	50.0	113	2370	4110	5480
K	50.0	108	2200	3870	5530
L	47.3	109	2680	4170	5650
M	48.5	104	2590	4120	5550
N					
O	47.3	112	2366	4008	5400
P	49.5	107	2620	4230	5400
Q					
S	50.0	103	2444	4025	5150
T	46.6	114	2610	3750	5115
U	48.5	98	2580	3990	5500
V	54.8	106	2340	4370	5940
W	50.6	106	2154	3600	5042
X	50.0	112	2191	3645	4783
Y	-	-	-	-	-
Z	47.0	110	2510	4380	5830
XX	-	-	-	-	-
ZZ	-	-	-	-	-
YY	52.8	100	2005	3475	5160
VV	49.0	103	2225	3700	4900
AA	48.0	103.5	2444	3983	5225

TABLE 18

Chemical Analysis

Test Sample No. 21

Participant	Chemical Analysis					
	L.O.I., %	Insoluble, %	SO ₃ , %	Fe ₂ O ₃ , %	Al ₂ O ₃ , %	MgO, %
A	1.62	0.35	2.24	2.90	5.48	1.55
B	1.58	0.32	2.18	2.86	5.35	1.19
C	1.52	0.25	2.20	2.87*	5.30*	1.52*
D	1.62	0.30	2.16	2.78	5.42	1.67
E	1.63	0.32	2.20	2.86	5.42	1.56
F	1.60	0.33	2.14	2.78	5.35	1.54
G	1.55	0.32	2.28	2.82	5.56	1.58*
H	1.60	0.39	2.26	2.88	5.58	1.72
I	-	-	-	-	-	-
J	1.52	0.33	2.23	2.85	5.92	1.70
K	1.58	0.38	2.22	2.80	5.62	1.57*
L	1.52	0.35	2.05	2.88	5.64	1.70
M	1.67	0.35	2.26	2.86	5.42	1.33
N	1.71	0.35	2.23	2.84	5.56	1.45
O	1.65	0.14	2.12	2.88	5.00	1.46
P	1.66	0.44	2.30	2.89	5.47	1.56
Q	1.59	0.33	2.25	2.82	5.80	1.59
S	1.43	0.38	2.16	2.89	5.43	1.50
T	1.46	0.45	2.35	2.91	5.44	1.66
U	1.65	0.40	2.22	2.89	5.35	1.78
V	1.74	0.08	2.14	3.02	5.48	1.34
W	1.54	0.25	2.23	2.86	5.92	1.33
X	1.65	0.24	2.22	2.90	5.32	1.59
Y	-	-	-	-	-	-
Z	1.54	0.35	2.21	2.80	5.62	1.73
XX	-	-	-	-	-	-
ZZ	-	-	-	-	-	-
YY	1.62	0.40	2.16	2.86	4.57	1.55
VV	1.60	0.22	2.05	2.91	5.65	1.30
AA	1.84	0.29	2.17	2.86	5.50	1.73

TABLE 19

Summary of Statistical Analysis of Test Results - Sample No. 16

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	29	%	25.9	23.0	23.9	0.60	2.5
- Rod Pen.	27	mm	11.0	9.0	9.9	0.62	6.3
Vicat Setting Time - Initial	29	hr:min	3:14	2:00	2:43	0:16	9.6
- Final	27	hr:min	5:30	3:25	4:27	0:32	11.9
Fineness - Retained on 200 M	29	%	11.1	2.2	5.54	1.70	30.6
- Blaine	27	cm ² /g	3208	2948	3071	64	2.1
Soundness - Autocl. Expansion	29	%	0.07	0.016	0.050	0.012	25.2
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	27	psi	3260	2090	2840	236	8.3
" " , 7-day	28	psi	4108	2950	3524	257	7.3
" " , 28-day	28	psi	5225	4130	4560	256	5.6
Water Content	26	%	54.0	45.5	47.8	1.9	3.9
<u>Chemical Analysis</u>							
Loss on Ignition	28	%	2.21	1.29	1.59	0.15	9.4
Insoluble	28	%	0.58	0.28	0.42	0.06	15.0
Sulphur Trioxide (SO ₃)	28	%	2.32	2.12	2.24	0.05	2.3
Ferric Oxide (Fe ₂ O ₃)	28	%	2.35	1.96	2.15	0.07	3.2
Alumina (Al ₂ O ₃)	28	%	5.33	4.25	4.53	0.22	4.9
Magnesia (MgO)	28	%	3.58	2.10	2.95	0.27	9.3

* n - Number of laboratories reporting.

TABLE 20

Summary of Statistical Analysis of Test Results - Sample No. 17

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	28	%	26.2	23.5	24.3	0.59	2.4
- Rod Pen.	26	mm	11.0	9.0	9.8	0.75	7.6
Vicat Setting Time - Initial	28	hr:min	3:15	1:54	2:30	0:17	11.1
- Final	26	hr:min	5:55	3:10	4:21	0:41	15.8
Fineness - Retained on 200M	27	%	2.1	0.8	1.47	0.39	26.5
- Blaine	28	cm ² /g	3630	3211	3467	79	2.3
Soundness - Autocl. Expansion	28	%	+0.030	-0.020	+0.0004	0.012	-
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	28	psi	3330	2067	2861	320	11.2
" " 7-day	29	psi	4540	2985	3683	329	8.9
" " 28-day	29	psi	6140	4125	4962	436	8.8
Water Content	23	%	53.0	44.6	47.6	1.9	4.1
<u>Chemical Analysis</u>							
Loss on Ignition	28	%	1.75	1.27	1.47	0.12	8.3
Insoluble	28	%	0.30	0.10	0.18	0.05	25.0
Sulphur Trioxide (SO ₃)	28	%	2.39	1.93	2.09	0.09	4.3
Ferric Oxide (Fe ₂ O ₃)	28	%	3.16	2.76	2.97	0.08	2.7
Alumina (Al ₂ O ₃)	28	%	5.68	3.85	4.43	0.39	8.9
Magnesia (MgO)	28	%	2.18	1.17	1.52	0.23	15.1

* n - Number of laboratories reporting.

TABLE 21

Summary of Statistical Analysis of Test Results - Sample No. 18

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	28	%	27.0	24.2	25.1	0.66	2.6
- Rod Pen.	24	mm	11.0	9.0	9.9	0.71	7.2
Vicat Setting Time - Initial	28	hr:min	3:10	2:00	2:37	0:17	10.6
- Final	27	hr:min	5:30	3:40	4:32	0:28	10.3
Fineness - Retained on 200M	26	%	7.1	2.0	3.45	1.12	32.5
- Blaine	27	cm /g	3398	3160	3328	55	1.6
Soundness - Autocl. Expansion	28	%	0.070	0.020	0.051	0.014	27.7
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	28	psi	3115	2200	2777	233	8.4
" " , 7-day	28	psi	3775	2756	3468	239	6.9
" " , 28-day	28	psi	4775	3678	4443	257	5.8
Water Content	27	%	56.0	46.0	49.5	2.4	4.8
<u>Chemical Analysis</u>							
Loss on Ignition	27	%	1.39	0.95	1.19	0.10	8.6
Insoluble	27	%	0.53	0.22	0.35	0.07	18.9
Sulphur Trioxide (SO ₃)	27	%	2.97	2.56	2.77	0.09	3.2
Ferric Oxide (Fe ₂ O ₃)	27	%	2.22	2.03	2.14	0.05	2.3
Alumina (Al ₂ O ₃)	27	%	6.39	4.11	5.83	0.40	6.9
Magnesia (MgO)	27	%	3.25	2.14	2.83	0.24	8.6

* n - Number of laboratories reporting.

TABLE 22

Summary of Statistical Analysis of Test Results - Sample No. 19

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	28	%	27.0	24.8	25.8	0.56	2.2
- Rod Pen.	26	mm	11.0	6.5	9.7	0.88	9.1
Vicat Setting Time - Initial	28	hr:min	3:20	1:20	2:23	0:24	17.1
- Final	26	hr:min	5:30	3:20	4:16	0:35	13.8
Fineness - Retained on 200 M	27	%	1.6	0.2	0.71	0.34	47.7
- Blaine	27	cm /g	3482	3120	3331	70	2.1
Soundness - Autocl. Expansion	27	%	0.52	0.12	0.322	0.109	33.9
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	28	psi	3075	2010	2462	232	9.4
" " , 7-day	28	psi	4440	3060	3867	291	7.5
" " , 28-day	27	psi	6110	4500	5323	398	7.5
Water Content	28	%	56.0	46.6	49.4	2.0	4.0
<u>Chemical Analysis</u>							
Loss on Ignition	26	%	2.07	0.98	1.65	0.18	10.7
Insoluble	26	%	0.29	0.06	0.15	0.06	38.4
Sulphur Trioxide (SO ₃)	27	%	2.01	1.84	1.93	0.05	2.5
Ferric Oxide (Fe ₂ O ₃)	27	%	2.04	1.73	1.86	0.06	3.2
Alumina (Al ₂ O ₃)	27	%	5.29	4.26	4.73	0.23	4.9
Magnesia (MgO)	27	%	4.02	3.02	3.52	0.21	5.8

* n - Number of laboratories reporting.

TABLE 23

Summary of Statistical Analysis of Test Results - Sample No. 20

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	26	%	25.6	24.0	24.7	0.41	1.7
- Rod Pen.	24	mm	11.0	9.0	10.0	0.67	6.7
Vicat Setting Time - Initial	26	hr:min	2:40	1:30	1:52	0:16	14.6
- Final	24	hr:min	4:10	2:40	3:27	0:27	13.1
Fineness - Retained on 200 M	26	%	5.6	2.0	3.79	0.93	24.5
- Blaine	26	cm ² /g	3335	3110	3214	52	1.6
Soundness - Autocl. Expansion	25	%	0.100	0.010	0.064	0.020	31.9
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	26	psi	2942	1905	2449	249	10.2
" " , 7-day	26	psi	3875	2425	3142	295	9.4
" " , 28-day	25	psi	5325	3542	4166	415	9.9
Water Content	26	%	54.7	46.4	48.9	2.0	4.1
<u>Chemical Analysis</u>							
Loss on Ignition	26	%	1.39	1.09	1.20	0.08	6.7
Insoluble	26	%	0.48	0.08	0.23	0.08	35.6
Sulphur Trioxide (SO ₃)	26	%	2.81	2.13	2.68	0.13	4.7
Ferric Oxide (Fe ₂ O ₃)	26	%	2.43	2.24	2.34	0.04	1.8
Alumina (Al ₂ O ₃)	26	%	6.41	4.96	5.73	0.23	4.1
Magnesia (MgO)	26	%	2.95	1.71	2.12	0.26	12.0

* n - Number of laboratories reporting.

TABLE 24

Summary of Statistical Analysis of Test Results - Sample No. 21

Description of Tests	n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
<u>Physical Tests - General</u>							
Normal Consistency - W/C	26	%	25.0	23.4	24.3	0.42	1.7
- Rod Pen.	25	mm	11.0	9.0	9.9	0.71	7.2
Vicat Setting Time - Initial	25	hr:min	3:15	1:30	1:58	0:21	18.2
- Final	24	hr:min	4:40	2:25	3:43	0:36	16.3
Fineness - Retained on 200 M	26	%	6.4	2.3	4.41	0.98	22.2
- Blaine	26	cm ² /g	3182	3030	3096	38	1.2
Soundness - Autocl. Expansion	25	%	0.130	-0.003	0.098	0.026	26.3
<u>Physical Tests - Mortar Strength</u>							
Compressive Strength, 3-day	25	psi	2680	1925	2371	203	8.6
" " , 7-day	25	psi	4380	3096	3911	292	7.5
" " , 28-day	25	psi	5940	4365	5254	368	7.0
Water Content	25	%	54.8	47.0	49.4	1.8	3.7
<u>Chemical Analysis</u>							
Loss on Ignition	26	%	1.84	1.43	1.60	0.09	5.4
Insoluble	26	%	0.45	0.14	0.32	0.08	26.4
Sulphur Trioxide (SO ₃)	26	%	2.35	2.05	2.20	0.07	3.1
Ferric Oxide (Fe ₂ O ₃)	26	%	3.02	2.78	2.86	0.05	1.7
Alumina (Al ₂ O ₃)	26	%	5.92	4.57	5.47	0.27	4.9
Magnesia (MgO)	26	%	1.78	1.19	1.55	0.15	9.8

* n - Number of laboratories reporting.

APPENDIX C

Laboratory Rating Procedure

Each laboratory is allotted a number of points according to the deviation of its own test results from the average of all lab results. For each range, limits expressed in terms of standard deviation S, points are given as follows:

Values in the range	average + 1S	1 point
" " " "	average - 1S	-1 "
" " " "	average + 1S to average + 2S ..	2 "
" " " "	average - 1S to average - 2S ..	-2 "
" " " "	average + 2S to average + 3S ..	3 "
" " " "	average - 2S to average - 3S ..	-3 "
Values beyond	average + 3S	4 "
" " " "	- 3S	-4 "

Values equal to the average are considered to fall in the first range and are allotted 1 point.

The over-all laboratory rating is obtained from the following formula:

$$R = \sqrt{\frac{\sum P^2}{N}}$$

where R = rating index

P = allotted points on each test

N = number of tests

The optimum rating index is 1.00 and decreasing laboratory efficiency is indicated by a rising rating index.

TABLE 25
Laboratory Ratings for Physical Tests - Phase III

Lab No.	Rating for Sample No.						Average for All Samples
	16	17	18	19	20	21	
A	1.15	1.49	1.22	1.66	1.00	1.12	1.27
B	1.00	1.37	1.12	1.22	1.50	1.47	1.28
C	1.00	1.70	1.24	1.66	1.38	1.41	1.40
D	2.21	2.31	1.50	1.89	1.66	2.52	2.01
E	1.15	1.15	1.12	1.12	1.12	1.47	1.19
F	1.15	1.00	1.12	1.12	1.12	1.00	1.08
G	1.00	1.00	1.12	1.41	1.12	1.32	1.16
H	1.15	1.63	1.22	1.66	1.50	1.38	1.42
I	2.24	1.90	2.15	2.00	-	-	2.07
J	1.53	1.29	1.78	1.22	1.38	1.12	1.39
K	1.15	1.15	1.22	1.12	1.38	1.38	1.23
L	1.86	1.41	1.24	1.88	1.87	1.41	1.61
M	1.15	1.15	1.00	1.73	1.12	1.50	1.27
N	1.46	1.46	-	1.38	1.26	1.15	1.34
O	1.15	1.15	1.50	1.00	1.12	1.13	1.17
P	1.00	1.00	1.22	1.55	1.00	1.32	1.18
Q	1.41	1.17	1.47	1.22	1.12	1.17	1.26
S	1.41	1.00	1.22	1.32	1.32	1.12	1.23
T	1.29	1.29	1.22	1.12	1.47	1.91	1.38
U	1.00	1.00	1.35	1.24	1.00	1.14	1.12
V	1.53	1.29	1.58	1.63	1.83	1.63	1.58
W	1.29	1.29	1.71	1.32	1.41	1.50	1.42
X	1.15	1.29	1.22	1.00	1.50	1.32	1.25
Y	1.29	1.29	1.41	1.12	-	-	1.28
Z	1.53	1.53	1.66	2.02	1.89	1.41	1.67
XX	1.60	2.05	1.76	-	-	-	1.80
ZZ	1.91	2.05	-	-	-	-	1.98
YY	2.20	2.35	2.52	2.12	2.36	1.73	2.21
VV	1.60	1.29	1.58	1.15	1.32	1.50	1.41
AA	-	-	1.22	1.12	1.22	1.00	1.14

TABLE 26
Laboratory Ratings for Chemical Tests - Phase III

Lab No.	Rating for Sample No.						Average for All Samples
	16	17	18	19	20	21	
A	1.00	1.22	1.00	1.83	1.22	1.00	1.21
B	1.00	1.22	1.41	1.41	1.91	1.53	1.41
C	1.68	1.73	1.41	1.83	1.58	1.00	1.54
D	1.87	1.22	1.96	1.22	1.22	1.22	1.45
E	1.22	1.00	1.00	1.00	1.00	1.00	1.04
F	-	-	-	1.22	1.68	1.22	1.37
G	1.22	1.00	1.22	1.22	1.83	1.22	1.28
H	1.53	1.00	1.58	-	1.22	1.22	1.31
I	1.83	1.22	1.68	1.53	-	-	1.56
J	1.00	2.20	1.00	1.41	1.00	1.22	1.30
K	1.22	1.53	1.00	1.22	1.00	1.22	1.20
L	1.00	1.82	1.58	1.00	1.00	1.53	1.32
M	1.00	1.22	1.22	1.22	1.22	1.22	1.18
N	1.00	1.00	-	2.40	1.00	1.22	1.32
O	1.53	1.41	1.83	1.41	1.68	1.83	1.61
P	1.22	1.00	1.00	1.41	1.00	1.41	1.17
Q	1.22	1.00	1.00	1.41	1.22	1.22	1.18
S	1.00	1.22	1.00	1.00	1.41	1.22	1.14
T	1.53	1.58	1.00	1.68	1.41	1.83	1.50
U	1.22	1.00	1.00	1.22	1.83	1.22	1.25
V	1.00	1.68	1.58	1.83	1.87	2.42	1.73
W	1.22	1.41	1.22	1.41	1.00	1.41	1.28
X	2.00	1.41	1.22	1.00	1.22	1.00	1.31
Y	1.41	2.16	2.16	1.22	-	-	1.74
Z	1.22	1.00	1.00	1.41	1.00	1.41	1.17
XX	1.41	1.68	1.41	-	-	-	1.50
ZZ	2.24	2.31	-	-	-	-	2.27
YY	1.68	1.22	2.58	1.41	2.71	1.87	1.91
VV	1.22	1.41	1.41	1.22	1.22	1.83	1.38
AA	-	-	1.00	2.12	1.00	1.68	1.45