Unclassified

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

IR 72-21 May 1972

EFFECT OF VARIATIONS IN STANDARD SAND ON COMPRESSIVE STRENGTH OF MORTAR CUBES

by

N. G. Zoldners and G. G. Carette

Mineral Processing Division

Unclassified

Mines Branch Investigation Report IR 72-21

EFFECT OF VARIATIONS IN STANDARD SAND ON COMPRESSIVE STRENGTH OF MORTAR CUBES

by

N. G. Zoldners* and G. G. Carette**

- - -

SUMMARY OF RESULTS

The results of standard mortar tests made by 28 laboratories in Canada using both the monitor and laboratory standard sand in four cement test series indicate the following.

Sieve analyses from about 20 per cent of the laboratories show that standard sand failed to comply with CSA specification requirements for the sieve fraction retained on sieve No. 50.

Variation in grading of standard sand fails to show significant relationship with water requirement and compressive strength results obtained by the participating laboratories.

The overall average compressive strength obtained in the four cement test series on mortar cubes made with monitor sand (4775 psi) was about the same as that of companion cubes made with laboratory standard sands (4780 psi).

---

*Head, Construction Materials Section, and **Engineer, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

CONTENTS

TABLES

INTRODUCTION

The unsatisfactory performance of standard Ottawa silica sand in recent years is a matter of considerable concern for the CSA Committee on Hydraulic Cements.

A study of the effects of variation in the quality of the graded standard sand, Type ASTM C 109, (Clause 8.5.3.2, Ref. 1) was done by C. J. Freming, Chief Project Chemist, Canada Cement Lafarge Ltd., and in an interim report[2] was submitted to the Committee on October 25, 1968. It was concluded that the quality of the supposedly standard sand varies and that this is reflected by the compressive strengths of the standard mortar test cubes.

To explore this comprehensively, the CSA Committee decided to initiate co-operative test series. The Mines Branch prepared and distributed identical monitor samples of the graded sand (Type ASTM C 109) with current samples of cement to participants in the CSA Co-operative Cement Testing Programme (see Appendix A).

SCOPE

Both monitor and laboratory standard sands were used with four different cement samples in standard mortar cube tests. The water requirements, flow and 3-, 7- and 28-day compressive strengths of mortar cubes were reported for both sand series. Statistical analyses of compressive strengths reported by different laboratories in both the monitor and laboratory sand series were used to evaluate the influence of the sand on the mortar cube strengths for each cement sample.

PARTICIPATING LABORATORIES

The participants in this investigation were mainly the same as for Phase III of the CSA Co-operative Cement Testing Programme and, in any test on any of the four cement series, varied between 23 and 28. This includes only those who reported corresponding test results for both sands. All participating laboratories are listed in Appendix B.

PREPARATION AND DISTRIBUTION OF TEST SAMPLES

A. Cement Test Samples

For this investigation, four test series were made up from samples No: 18, 19, 20, and 21 of the Co-operative Cement Testing Programme (Phase III). Each sample was prepared and distributed among participating laboratories as specified in the above programme.

B. Monitor Standard Sand Sample

Two sets of monitor sand samples were prepared from two 10-bag lots of the graded standard sand. The first lot was supplied by Mr. J. Laneuville, Research Director of St. Lawrence Cement Company, Clarkson, Ontario, in January 1969. The second lot was received from Mr. J. Polins of the Ottawa Silica Sand Company, Delson, Quebec, in December 1969.

The ten bags of each of the two lots of sand were mixed in an Ehrsam tumbler mixer (Model TM 10), capacity of which is 10 cu ft. After 15 min of mixing, the blended material was dumped into tubs and riffled into 32 samples of about 15 to 17 lb each. Sand samples were packed in plastic bags and shipped to the participating laboratories as follows:

The first series of monitor sand samples was sent simultaneously with cement sample No. 18 in February 1969 and the second with cement sample No. 20 in February 1970. The first monitor sand sample was for use with cement samples No. 18 and 19, and the other one was with samples No. 20 and 21.

Sieve analyses of the monitor sand are given in Table I. Also shown are the ASTM C 109 specification limits for the standard sand.

TABLE I

Sieve Analysis of Monitor Sand*

Sieves	Percentage Retained		
	Monitor Sand		ASTM Specif.
	Lot 1	Lot 2	Limits
No. 100 (149-μ)	98.5	98.9	98±2
No. 50 (297-μ)	74.8	72.8	72±5
No. 30 (595-μ)	0.3	0.9	2±2
No. 16 (1.19mm)	0.0	0.0	0

* Average of eight samples of each lot.

TEST PROCEDURES

Each laboratory was requested to determine the compressive strengths of mortars using both its own supply of standard sand and the monitor sand. The test procedures were as shown in Appendix A.

Each participant was also requested to report the water content used in the mortar and to make sieve analysis of its laboratory sand used for each of the four cement test samples.

TEST RESULTS

Test data reported by each participating laboratory included the 3-, 7-, and 28-day compressive strengths, amounts of water needed for the required flow of mortar, as well as the sieve analyses of laboratory standard sand and, in some cases, that of the monitor sand.

A. Compressive Strength

The reported results were tabulated and statistically analysed. The results of these analyses are shown in Tables 1 to 4, Appendix C. The summary of the coefficients of variation C.V. from the four test series is shown in Table II.

TABLE II

Summary of Coefficients of Variation of Strength Results
(Monitor vs laboratory standard sand)

Test		Coefficient of Variation, C.V. Per Cent				
		Sample No. 18	Sample No. 19	Sample No. 20	Sample No. 21	Average
Compressive Strength						
Monitor Sand	3-day	6.8	8.3	9.1	6.9	7.8
	7-day	5.5	7.7	7.9	6.9	7.0
	28-day	5.2	8.0	5.9	7.0	6.5
	Water content	4.1	3.7	3.7	3.4	3.7
Lab Sand	3-day	8.4	8.5	10.2	8.9	9.0
	7-day	6.9	7.8	9.4	7.8	8.0
	28-day	5.8	7.7	9.9	6.8	7.5
	Water content	4.8	3.9	4.1	3.8	4.1

The 28-day compressive strengths of cement mortars made with the monitor sand are plotted against those of the laboratory standard sands in figures shown in Appendix D. Figure 1 covers results from test series with cement samples No. 18 and 19, and Figure 2 covers those with samples No. 20 and 21. A combined plot covering all four test series with 100 results is shown in Figure 3.

B. Water Content

Amounts of water used and the corresponding 28-day compressive strengths of mortar, obtained by each laboratory, with monitor and with its own standard sand, are shown graphically in Figures 4 to 7, Appendix E.

C. Sieve Analyses

Each participant provided sieve analysis data on laboratory standard sand used in testing each of the four cement samples. The percentages retained on No. 30, 50, and 100 sieves were compiled for each laboratory and cement sample, and are shown in Table 5 in Appendix F.

Table III summarizes and compares the variations in sand sieve analyses data for all participants.

TABLE III

Summary of Variations in Sieve Analyses
(Laboratory Standard Sands)

Cement Sample No.	Range in Variations of Percentage Retained		
	Sieve No. 30	Sieve No. 50	Sieve No. 100
18	0.0 to 3.0	61.5 to 79.8	92.5 to 99.4
19	0.0 to 1.5	68.2 to 82.8	95.6 to 99.3
20	0.0 to 2.0	64.0 to 80.6	96.1 to 99.8
21	0.0 to 1.5	68.7 to 81.0	96.0 to 99.8
ASTM Limits	2 ± 2	72 ± 5	98 ± 2

In Figures 8 to 11 (Appendix F), for each of the four cement series, some variables are plotted which may relate to the variation in mortar strength results between individual laboratories. These graphs show fineness modulus (F.M.) for each laboratory standard sand (arranged in decreasing order) and the differences (W_L-W_M) between water used with these sands and with the monitor

sand in per cent.

Also shown are the corresponding compressive strength differences.

DISCUSSION

A. Compressive Strength

The spreads between the maximum and the minimum 28-day strength from the four test series are from about 900 to 1700 psi for monitor and from about 1100 to 1800 psi for the laboratory sands. The "line of equality" in Figures 1 and 2 shows that, in the first two test series(18 and 19),mortars made with laboratory sands produced higher results than those made with monitor sand. In the last two series (20 and 21), the trend was reversed. The combined plot of 100 test results from all four test series shows a very balanced distribution along the line of equality. The grand average of all strength test results with the monitor sand was 4775 psi and that for laboratory sands was 4780 psi - the monitor sands have little, if any, different effect than the laboratory sands.

B. Water Content

The principal factor affecting strength properties of cement mortars is the amount of water needed to achieve the required flow. Amounts of water used with both the monitor and laboratory standard sands are shown for the four test series in Figures 4 to 7 (Appendix E). With water content for monitor sand arranged in increasing order, one would expect that the corresponding mortar strength should decrease accordingly. However, the strength results do not follow the expected trend and no relationship with the amounts of water can be established. Apparently water content is not the only factor affecting the mortar strength properties.

Though coefficients of variation C.V. for water content in each of the four test series, as shown in Table II, were smaller with monitor sand than those with laboratory sands, the compressive strengths of mortars in some series do not follow the same trend. The C.V. values for the 28-day compressive strength in test series for cement samples 19 and 21 are 8.0 and 7.0 per cent for the monitor sand against 7.7 and 6.8 per cent for laboratory sands, respectively. This indicates that, besides water content, there are other factors involved which may offset the beneficial, if any, influence of monitor sand on the uniformity of strength results.

C. Sand Grading

Another factor which may influence the water requirements and affect the compressive strength of mortar is the sand grading. Sieve analyses of standard sands used by each participant, as compiled in Table 5 (Appendix F), show that the grading varied considerably and, in some cases, failed to comply with the CSA specification requirements. This is particularly true in the amount of material retained on sieve No. 50. Test data from 20% of the laboratories exceed the 77% maximum limit specified by the CSA size distribution requirements (Table ii, Ref. 3). The F.M. values varied from 1.54 to 1.82 and are plotted in decreasing order in the upper part (a) of Figures 8 to 11 (Appendix F).

The corresponding amounts of water used for these sands were the same as for monitor sand or less. This is shown in the middle part (b) where the differences ($W_L - W_M$) are shown in per cent. In only two instances (Figure 11, Laboratories G and K), more water was used with the laboratory standard sands than with monitor sand. The F.M. of these two sands was 1.80 for G and 1.72 for K, whereas for monitor sand the F.M. = 1.75.

The corresponding strength value fluctuations of mortars made with each laboratory sand are shown in the lower part (c) where the differences ($S_L - S_M$) are plotted in psi values. Except for two cases, mortar strength decreases slightly with the decrease in F.M. values of sand.

The graphs shown in Figures 8 to 11 (Appendix F) indicate that existing slight variation in the gradings of standard sands used by different laboratories have little, if any effect on the mortar strengths.

CONCLUSION

No correlation exist between the variation in the grading and water requirement of laboratory standard sands and the variation in compressive strengths reported by different laboratories.

The factors specific to individual laboratories such as variables in testing procedures have greater effect on the mortar strength than minor variations in sand grading or water content.

Under existing conditions, the use of identical monitor sand would not reduce significantly variations in compressive strength results between different testing laboratories in Canada.

REFERENCES

1. CSA Standard A5-1971, "Portland Cements", Canadian Standards Association, Rexdale, Ont., Canada, 1971.
2. Fremming, C.J., "Quality of Ottawa Silica Sand Supplied By The Ottawa Silica Company, Ottawa, Illinois", (An interim report), presented at the 18th Annual Meeting, CSA Committee on Hydraulic Cements, October 25, 1968, Ville d'Esterel, P.Q.

NGZ/GGC/am

APPENDIX A

CSA Cement Testing Programme - Phase III

1. Covering letter, February 1969
2. Instructions for Cement Testing

CANADA

Department of Energy, Mines and Resources
Ministère de l'Énergie, des Mines et des Ressources

MINERAL PROCESSING DIVISION

Mines Branch
Direction des mines

File Number
N° à rappeler

40 Lydia St., Ottawa 1, Ont.

February 1969

To: All Participants of CSA Cement Testing Programme

Gentlemen:

Re: CSA Cement Testing Programme - Phase III

It was requested at the 18th Annual Meeting of CSA Committee on Hydraulic Cements at Ville D'Esterel, October 25, 1968, that a sample of standard monitor sand (ASTM C 109) be sent along with the next cement test sample of the CSA Co-operative Cement Testing Programme.

We are sending you cement sample No. 18. Under separate cover we are also sending you approximately 15 lbs. of standard monitor sand, sufficient to cover your sand requirements for tests on cement samples No. 18 and No. 19. The latter sample (No. 19) will follow at a later date.

Please use this monitor sand with the cement test sample for mortar cube tests. Make also mortar cube tests using the same cement sample and your laboratory standard sand. Please enclose in your report the sieve analyses of your laboratory standard C 109 sand. This will provide us with comparative information on the effect of variations of standard sand grading upon mortar compressive strength. We are requesting your co-operation during these tests that strict adherence to testing and curing procedures and methods be followed. Also, the same cube moulds should be used and the same operators should perform the tests.

All tests are to be carried out as per the enclosed list of test procedures except for the last four tests of the chemical analyses. Other methods for these four tests may be employed, however, please indicate in your report the method involved for our records. The test results, reported on a separate sheet, are to be forwarded to this office immediately after completion of the tests.

In order that individual results are kept confidential, code numbers are assigned to each laboratory. Your laboratory is assigned No. , under which your tests results will be tabulated. Please use it as the laboratory identification in your correspondence when reporting test results to this office.

We appreciate very much your co-operation, which is so essential for the continued success of this cement testing programme.

Yours very truly,

N.G. Zoldners, Member,
CSA Committee on Hydraulic Cements

NGZ/mn

Re: CSA Cement Testing Programme - Phase III

INSTRUCTIONS FOR CEMENT TESTING

(as prepared by Mr. W.J. Prout, Member CSA Coordination Subcommittee)

PHYSICAL TESTS

Sample Preparation - CSA - A5 1961 Clause 5.2.5

1. Fineness by 200 mesh - CSA A5 1961 Clause 7.2

   Please report approximately age of sieve, if the sieve is certified, and if a correction factor as described in ASTM C 184-66 was applied to the results.

2. Fineness by Air Permeability - ASTM C-204-55.

3. Normal Consistency - CSA A5 1961*

   Please report % H_2O and rod penetration - Clause 7.1.4

4. Soundness - CSA A5 1961 Clause 7.3

5. Vicat Setting time - CSA A5 1961* - Clause 7.5

   To simplify future calculations, please report Vicat setting times in total minutes, e.g. 2 hr 10 min should be reported as 130 minutes.

6. Compressive Strength - CSA A5 1961 - Clause 7.8

   Please report 3,7,28 day comp. strength and % water used, and % flow in the Mortar.

CHEMICAL TESTS

In order to evaluate the current CSA referee analytical methods, participating laboratories are requested to follow CSA methods:

1. Loss on Ignition - CSA A5 1961 Clause 6.5.1

2. Insoluble Residue - CSA A5 1961 Clause 6.5.2

3. Sulphur Tioxide - CSA A5 1961 Clause 6.5.3

4. Ferric Oxide - CSA A5 1961
Clause 6.5.5

5. Alumina - CSA A5 1961
Clause 6.5.6 and 6.5.7
Use Clause 6.5.6.1 revision Oct 1964

6. Magnesia - CSA A5 1961
Clause 6.5.8
Use clause 6.6.8.1, 6.5.8.2, 6.5.8.3
revision Oct 1964

Note: Other analytical methods may be employed in addition to the referee methods, however these procedures should be briefly described and reported separately from the referee methods.

---

*Clause 7.1.4.1 - Mixing Cement Pastes was revised June 1967 to read as follows:

7.1.4.1 Mixing Cement Pastes - A 500 gram sample of dry cement shall be mixed with measured amount of clean water in a mechanical mixer in accordance with the following method:

Apparatus - The mixer, paddle, mixing bowl and scraper shall conform with the requirements of Clauses 7.8.4.3 (a) to (d) respectively; and

Procedure - Place the dry paddle and the dry bowl in the mixing position in the mixer. Then introduce the materials for a batch into the bowl and mix in the following manner:

(a) Place all the mixing water in the bowl

(b) Add the cement to the water and allow 30 seconds for the absorption of the water

(c) Start the mixer and mix at slow speed (140±5 rpm) for 30 sec.

(d) Stop the mixer for 15 seconds and during this time scrape down into the batch any paste that may have collected on the sides of the bowl; and

(e) Start the mixer at medium speed (285±10 rpm) and mix for 1 minute

APPENDIX B

Participating Laboratories and Organizations

Testing Laboratory/Organization	Location
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
Ministere de la Voirie	Quebec
Miron Company Ltd.	St. Michel
St. Lawrence Cement Company	Villeneuve
Ontario	
Canada Cement Lafarge Limited	Woodstock
Canada Cement Lafarge Limited	Belleville
Canada Cement Lafarge Limited	Port Colborne
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	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	
Ocean Cement Limited	Bamberton
Lafarge Cement of North America Ltd.	Lulu Island

APPENDIX C

Summary of Statistical Analyses of Strength Test Results

Tables 1, 2, 3, and 4

(Test Series - Cement Samples No. 18, 19, 20, and 21)

TABLE 1

Statistical Analysis of Strength Test Results - Sample No. 18
(Monitor vs Laboratory Standard Sand)

Description of Tests		n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
Mortar Cube Strength Test								
	3-day	28	psi	2950	2280	2735	186	6.8
Monitor	7-day	28	psi	3910	2960	3430	188	5.5
Sand	28-day	28	psi	4890	3962	4430	230	5.2
	Water content	27	%	55.3	48.0	49.9	2.0	4.1
	3-day	28	psi	3115	2200	2775	233	8.4
Lab	7-day	28	psi	3775	2756	3470	239	6.9
Sand	28-day	28	psi	4775	3678	4445	257	5.8
	Water content	27	%	56.0	46.0	49.5	2.4	4.8

*n - Number of laboratories reporting.

TABLE 2

Statistical Analysis of Strength Test Results - Sample No. 19
(Monitor vs Laboratory Standard Sand)

Description of Tests		n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
Mortar Cube Strength Test								
Monitor Sand	3-day	25	psi	2770	1990	2405	201	8.3
	7-day	25	psi	4430	2962	3770	289	7.7
	28-day	24	psi	6180	4550	5265	422	8.0
	Water content	25	%	56.0	47.8	49.7	1.8	3.7
Lab Sand	3-day	25	psi	2760	2010	2440	208	8.5
	7-day	25	psi	4440	3060	3860	299	7.8
	28-day	24	psi	6110	4500	5335	412	7.7
	Water content	25	%	56.0	46.6	49.3	1.9	3.9

*n - Number of laboratories reporting.

TABLE 3

Statistical Analysis of Strength Test Results - Sample No. 20
(Monitor vs Laboratory Standard Sand)

Description of Tests		n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
Mortar Cube Strength Test								
Monitor Sand	3-day	26	psi	2805	1602	2450	223	9.1
	7-day	26	psi	3500	2260	3150	250	7.9
	28-day	25	psi	4767	3810	4165	246	5.9
	Water content	26	%	54.7	47.3	49.4	1.8	3.8
Lab Sand	3-day	26	psi	2942	1905	2450	249	10.2
	7-day	26	psi	3875	2425	3140	295	9.4
	28-day	25	psi	5325	3542	4165	415	9.9
	Water content	26	%	54.7	46.4	48.9	2.0	4.1

*n - Number of laboratories reporting.

TABLE 4

Statistical Analysis of Strength Test Results - Sample No. 21
(Monitor vs Laboratory Standard Sand)

Description of Tests		n*	Unit	Maximum	Minimum	Average	Standard Deviation	Coefficient of Variation, %
Mortar Cube Strength Test								
	3-day	23	psi	2650	1937	2375	164	6.9
Monitor	7-day	23	psi	4340	3054	3950	271	6.9
Sand	28-day	23	psi	6100	4342	5340	374	7.0
	Water content	23	%	54.6	47.2	49.5	1.7	3.4
	3-day	23	psi	2680	1925	2370	211	8.9
Lab	7-day	23	psi	4380	3096	3910	305	7.8
Sand	28-day	23	psi	5940	4365	5290	358	6.8
	Water content	23	%	54.8	46.6	49.4	1.9	3.8

*n - Number of laboratories reporting.

APPENDIX D

Compressive Strength - Monitor vs Laboratory Standard Sands

Figures 1, 2, and 3

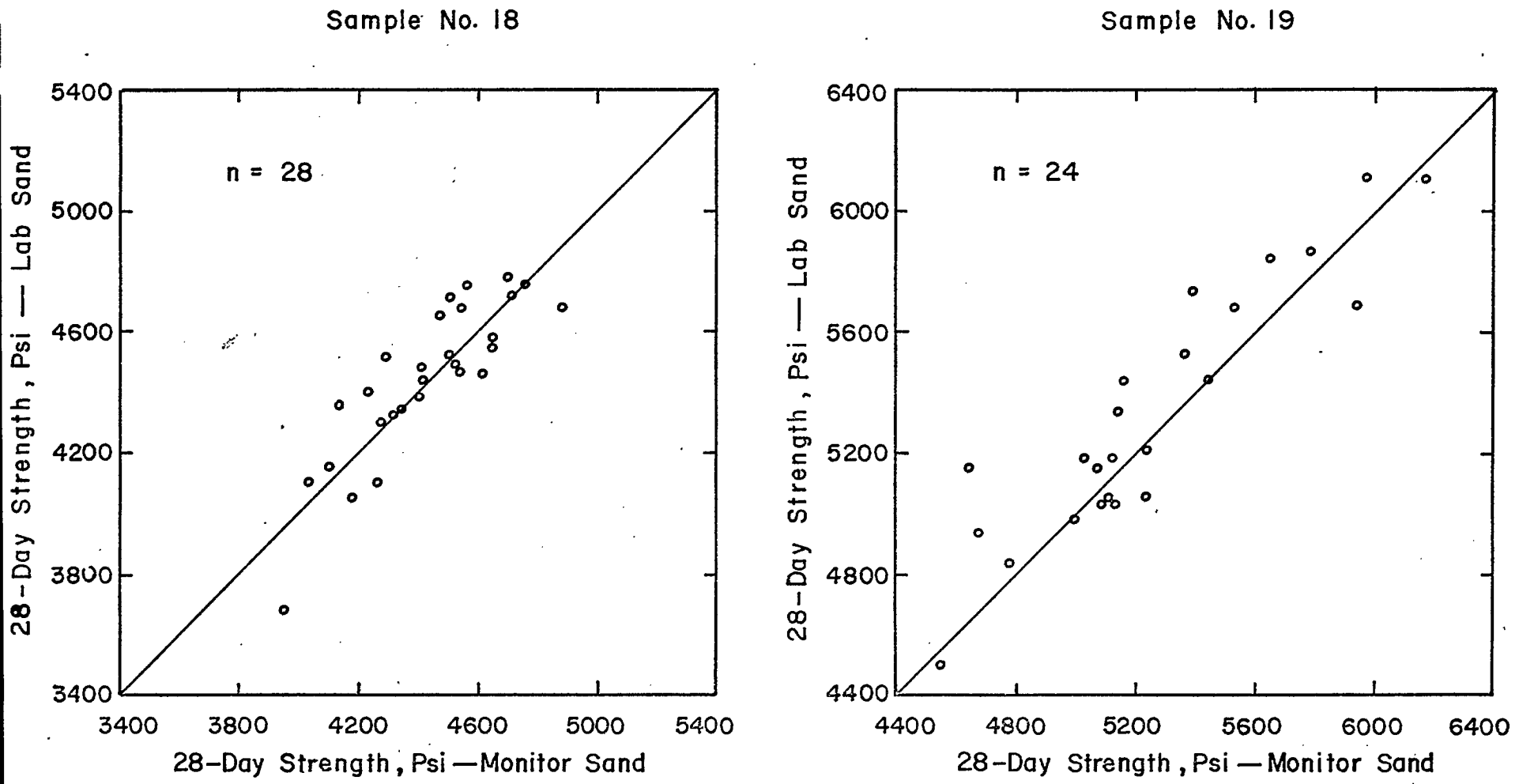

Fig. I — Strength Results of Mortar Cubes — Monitor vs Laboratory Sand
(CSA Cement Test Samples 18 and 19)

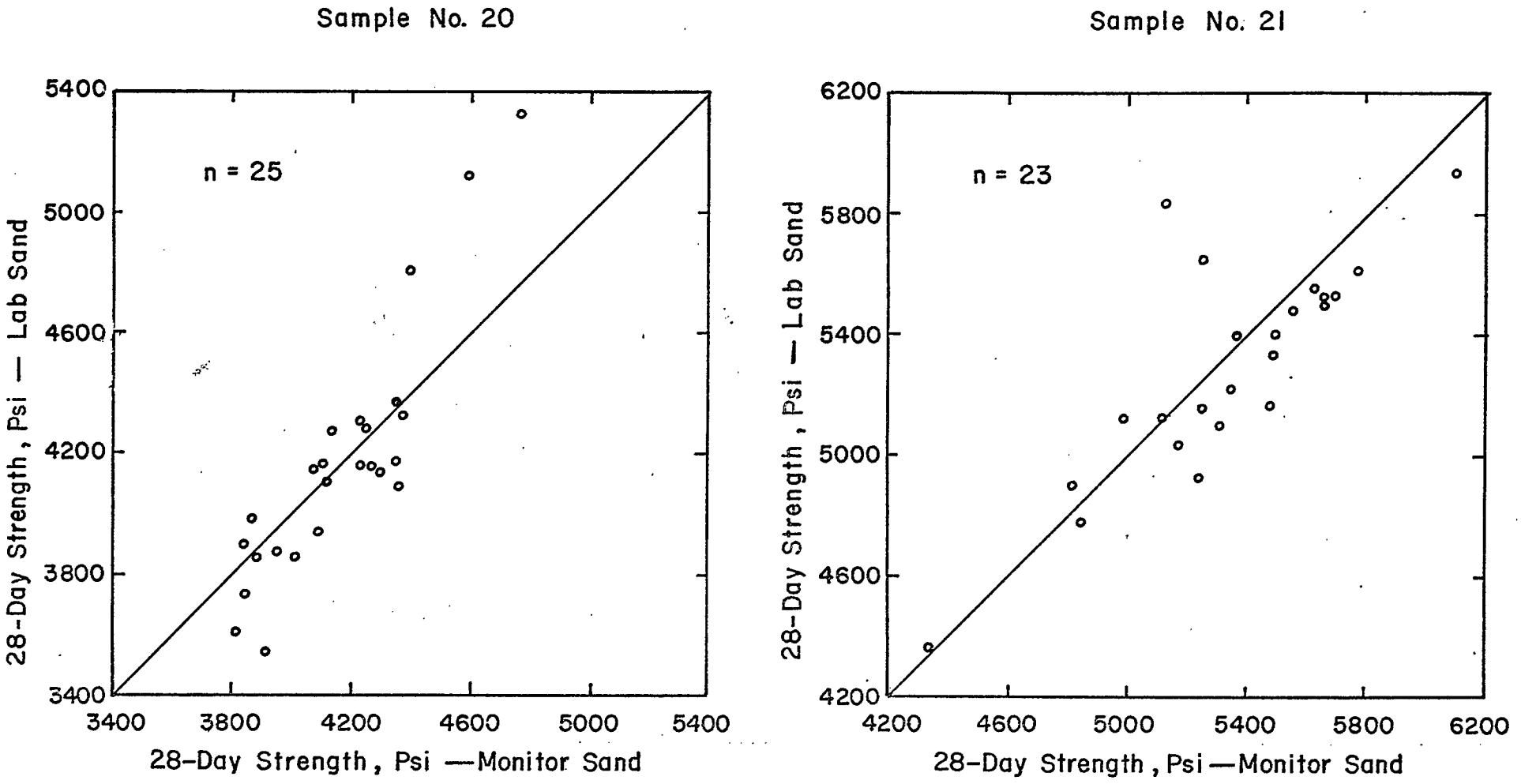

Fig. 2 — Strength Results of Mortar Cubes — Monitor vs Laboratory Sand
(CSA Cement Test Samples 20 and 21)

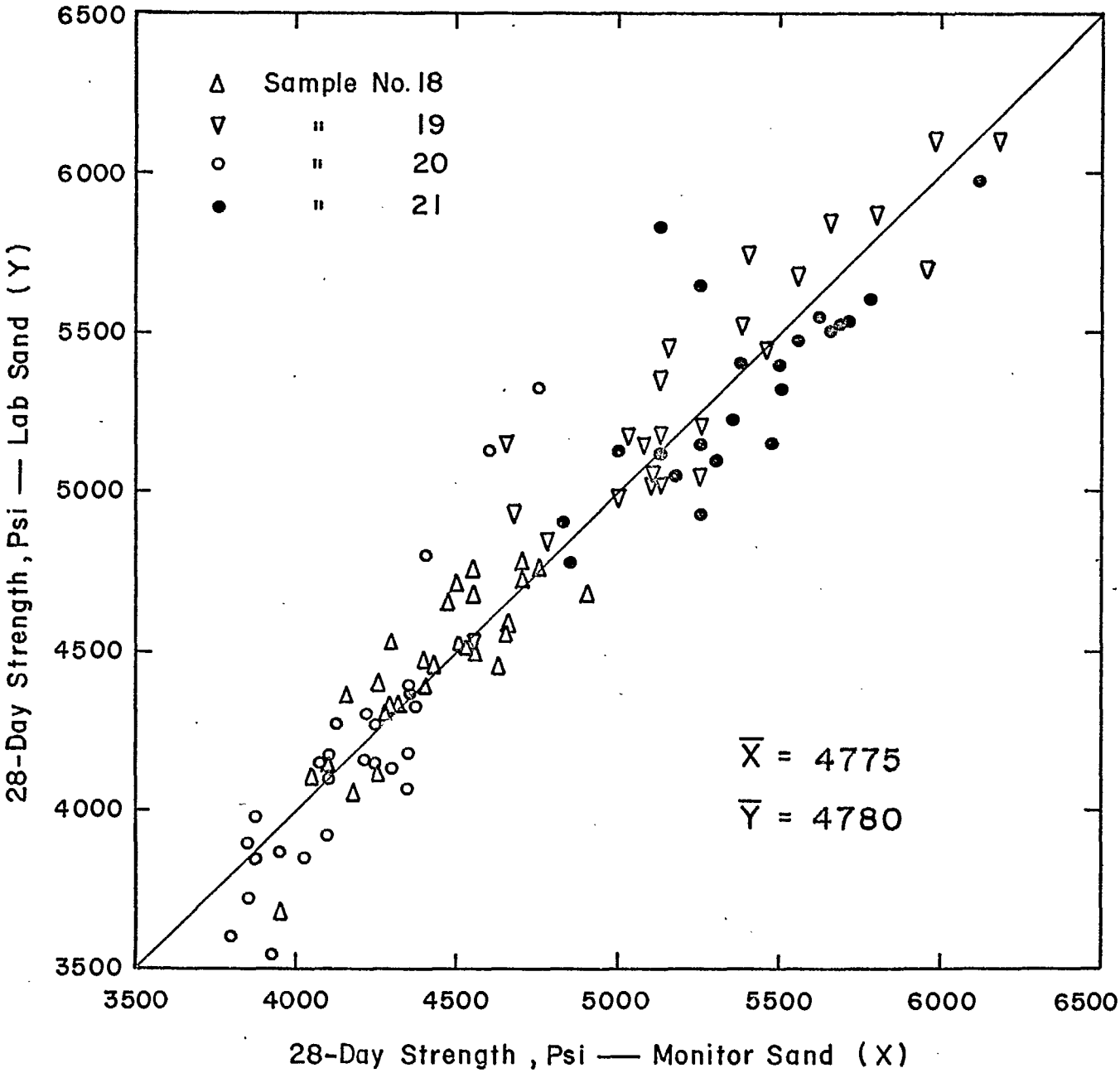

Fig. 3 — Combined Plot of Cube Strength Results — Monitor vs Laboratory Sand
(Cement Samples 18, 19, 20, and 21)

APPENDIX E

Water Content vs Compressive Strength of Mortar

Figures 4, 5, 6, and 7

(Test Series - Cement Samples No. 18, 19, 20, and 21)

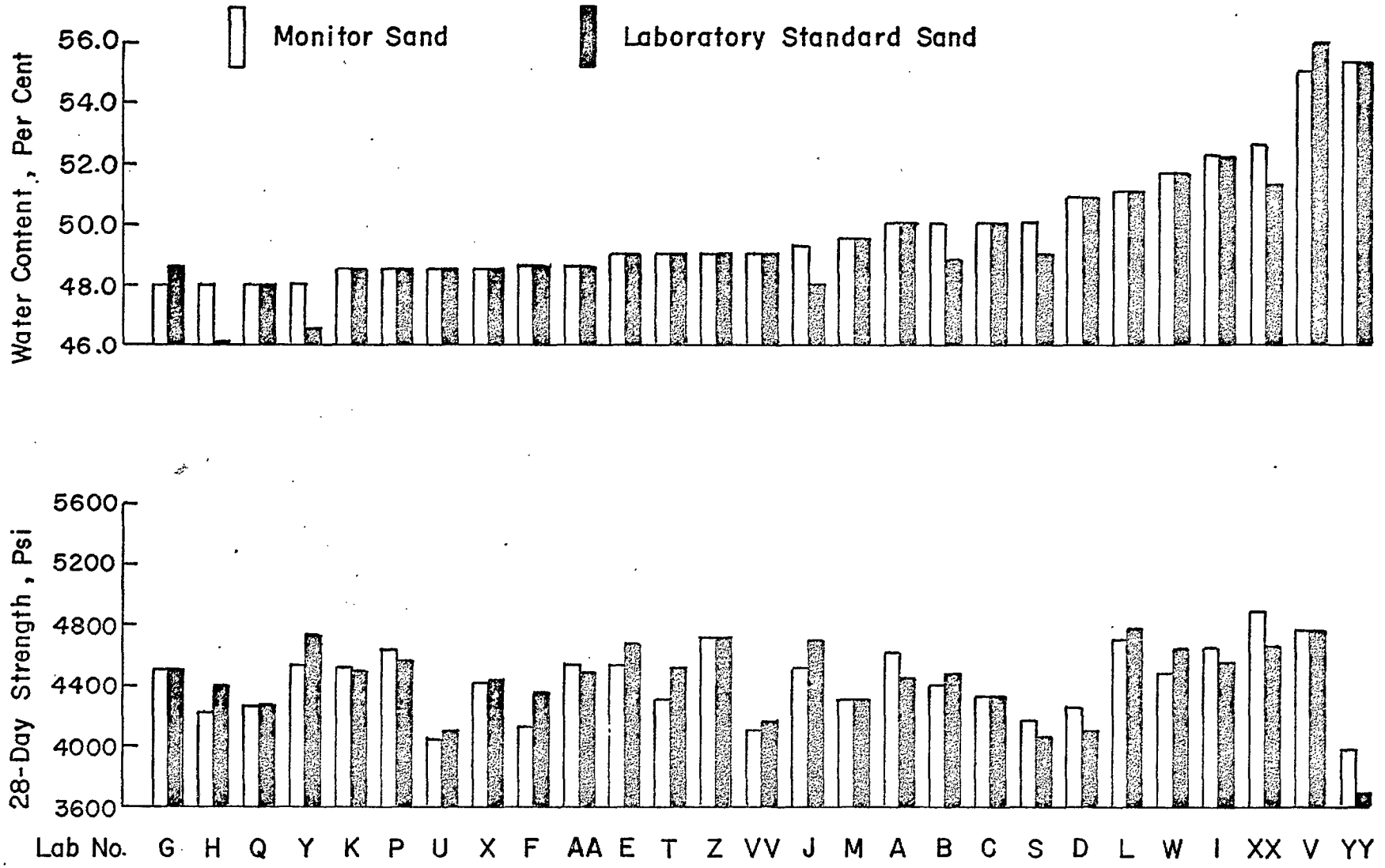

Fig. 4 — Water Content vs Compressive Strength of Mortar
(CSA Cement Sample No. 18)

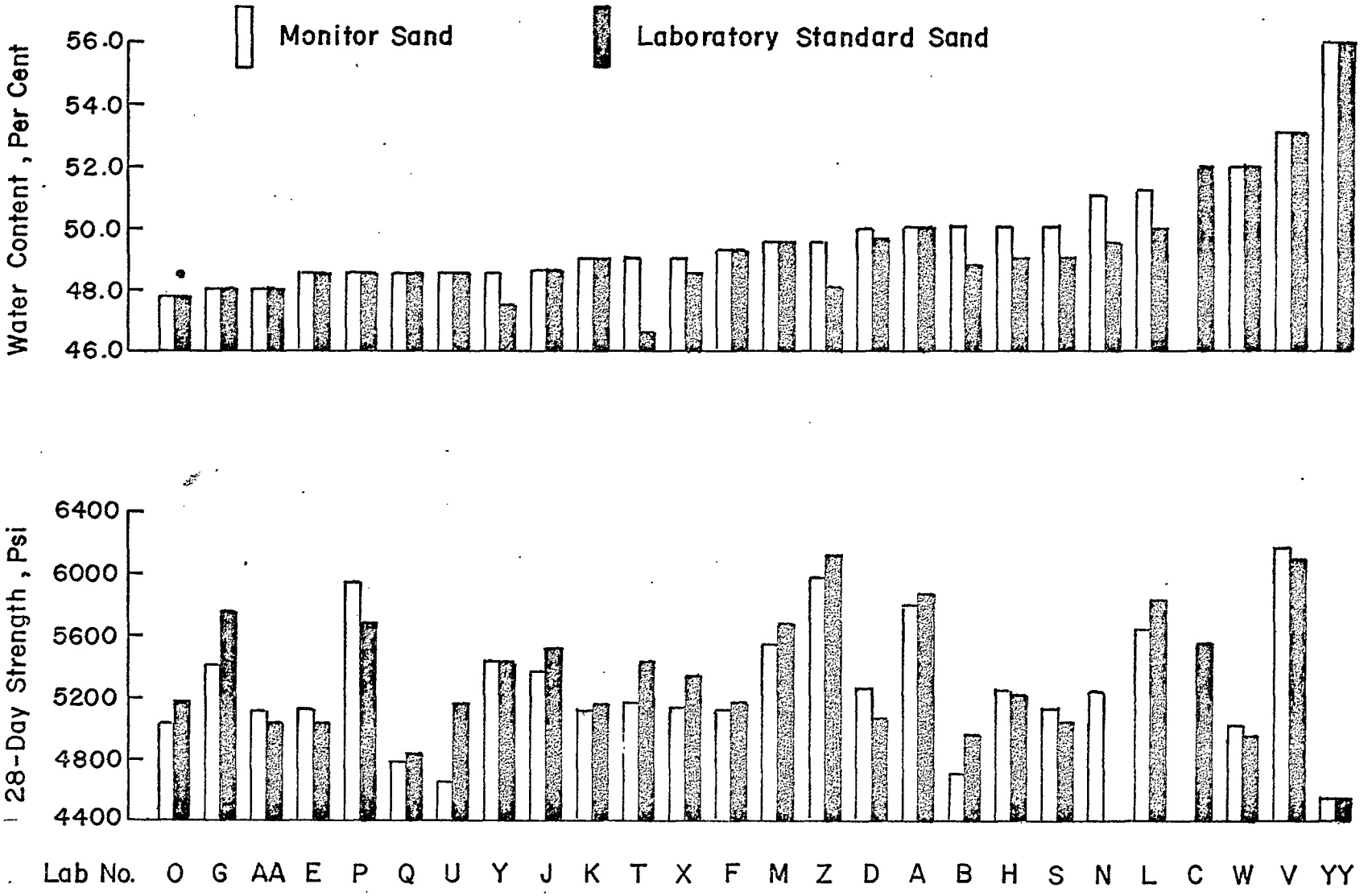

Fig. 5 — Water Content vs Compressive Strength of Mortar
(CSA Cement Sample No. 19)

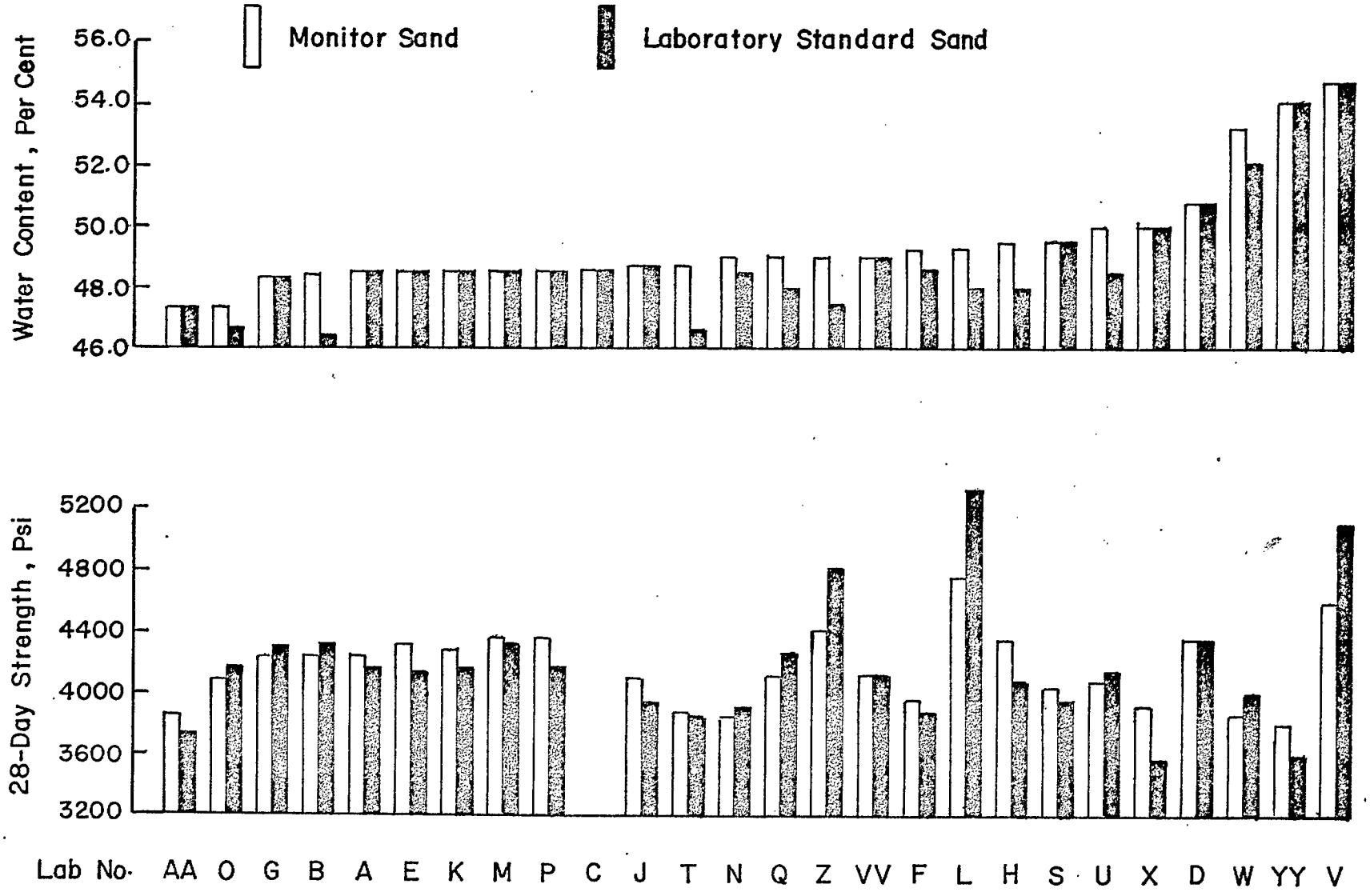

Fig. 6—Water Content vs Compressive Strength of Mortar
(CSA Cement Sample No. 20)

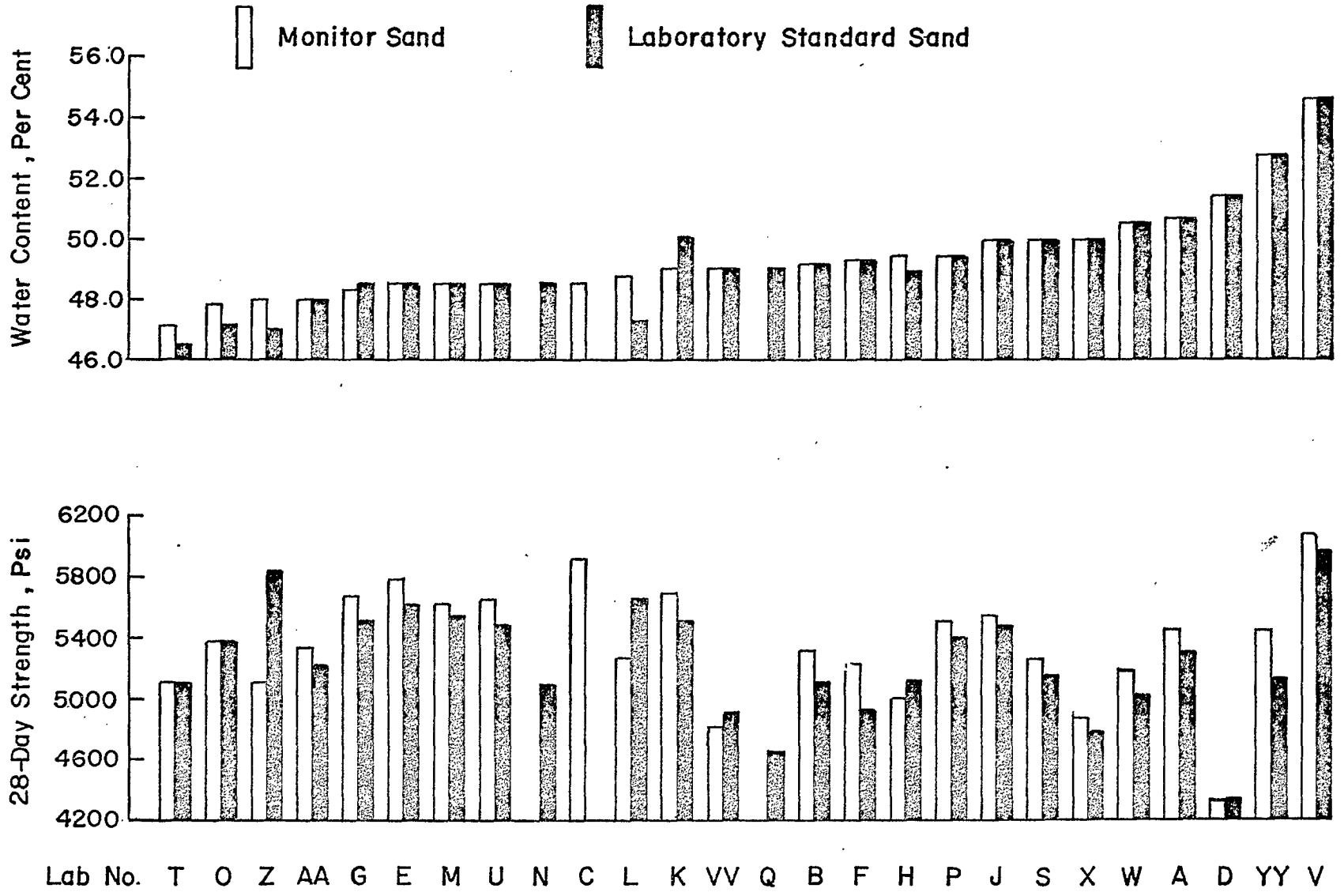

Fig. 7 — Water Content vs Compressive Strength of Mortar
(CSA Cement Sample No. 21)

TABLE 5 APPENDIX F

Summary of Laboratory Standard Sand Analysis

Lab	Percentage Retained											
	30 Mesh				50 Mesh				100 Mesh			
	Sample No. 18	Sample No. 19	Sample No. 20	Sample No. 21	Sample No. 18	Sample No. 19	Sample No. 20	Sample No. 21	Sample No. 18	Sample No. 19	Sample No. 20	Sample No. 21
A	0.1	0.0	0.0	0.0	67.0	76.0	71.0	71.0	93.4*	99.0	98.0	99.0
B	0.1	0.5	0.7	0.2	72.8	75.4	71.4	73.2	97.7	98.0	97.0	97.1
C	0.5		0.7		61.5*		64.0*		92.5*		96.9	
D	0.3	0.4	0.5	0.6	77.3*	78.5*	78.4*	75.1	99.4	98.9	98.6	98.0
E	0.0	0.3	0.1	0.0	67.3	73.6	74.1	72.0	96.7	98.9	98.2	98.9
F	0.3	0.3	0.3	0.3	74.6	74.6	75.6	75.6	99.3	99.3	99.4	99.4
G	0.5	0.2	0.4	0.4	69.9	76.1	79.8*	79.8*	94.0*	97.7	99.8	99.8
H	1.0	0.0	0.0	0.0	70.0	71.0	73.0	73.0	96.0	99.0	98.0	96.0
J	0.5	0.5	0.0	1.0	78.8*	82.8*	73.0	75.0	97.7	98.3	97.0	97.0
K	0.3	0.2	0.2	1.2	72.8	80.0*	77.0	71.5	98.1	98.4	98.7	98.5
L	0.4				75.8				98.7			
M	1.0	1.0	0.0	1.0	75.0	77.0	77.0	81.0*	99.0	99.0	99.0	99.0
O	0.2	0.2	0.3	0.3	69.0	68.4	75.9	75.9	98.2	98.1	98.7	98.7
P	0.1	0.3	0.1	0.2	69.8	74.2	76.7	80.0*	98.0	98.0	97.6	98.9
Q	0.5	0.2	0.3	0.6	71.7	75.0	80.6*	79.8*	93.4*	96.3	98.8	98.4
S	1.6	0.2	0.4	0.6	79.8*	72.0	74.1	71.1	97.4	95.6*	98.0	98.1
T	1.5	1.5	1.5	1.5	76.6	76.6	76.5	76.5	98.3	98.3	98.4	98.4
U	0.5	0.5	0.3		77.0	78.0*	77.1		99.0	99.0	98.4	
V			2.0				72.0				98.0	
W	0.2		0.1	0.7	74.6		78.7*	77.4*	97.9		98.5	97.4
X	1.0	1.0	1.0	1.0	77.0	77.0	74.5	76.0	97.0	97.0	96.7	97.0
Y	1.9				72.7				96.7			
Z	0.3	0.5	0.5	0.6	71.0	68.2	72.5	69.0	96.4	96.3	97.3	96.5
XX	0.6				69.4				96.8			
YY	0.1	0.2	1.1		72.1	72.4	68.5		98.5	98.8	98.6	
VV	3.0		0.0	0.1	73.5		68.7	68.7	99.0		96.1	96.1
AA	0.1	0.1	0.5	0.2	77.7*	77.7*	72.8	74.5	99.2	99.2	98.3	98.6
	0.6	0.4	0.5	0.5	72.9	75.2	74.3	74.8	97.2	98.2	98.1	98.0

* Failed to comply with CSA specification requirements.

APPENDIX G

Sand Grading vs Water Content and

Compressive Strength of Mortar

Figures 8, 9, 10 and 11

Cement Samples No. 18, 19, 20, and 21)

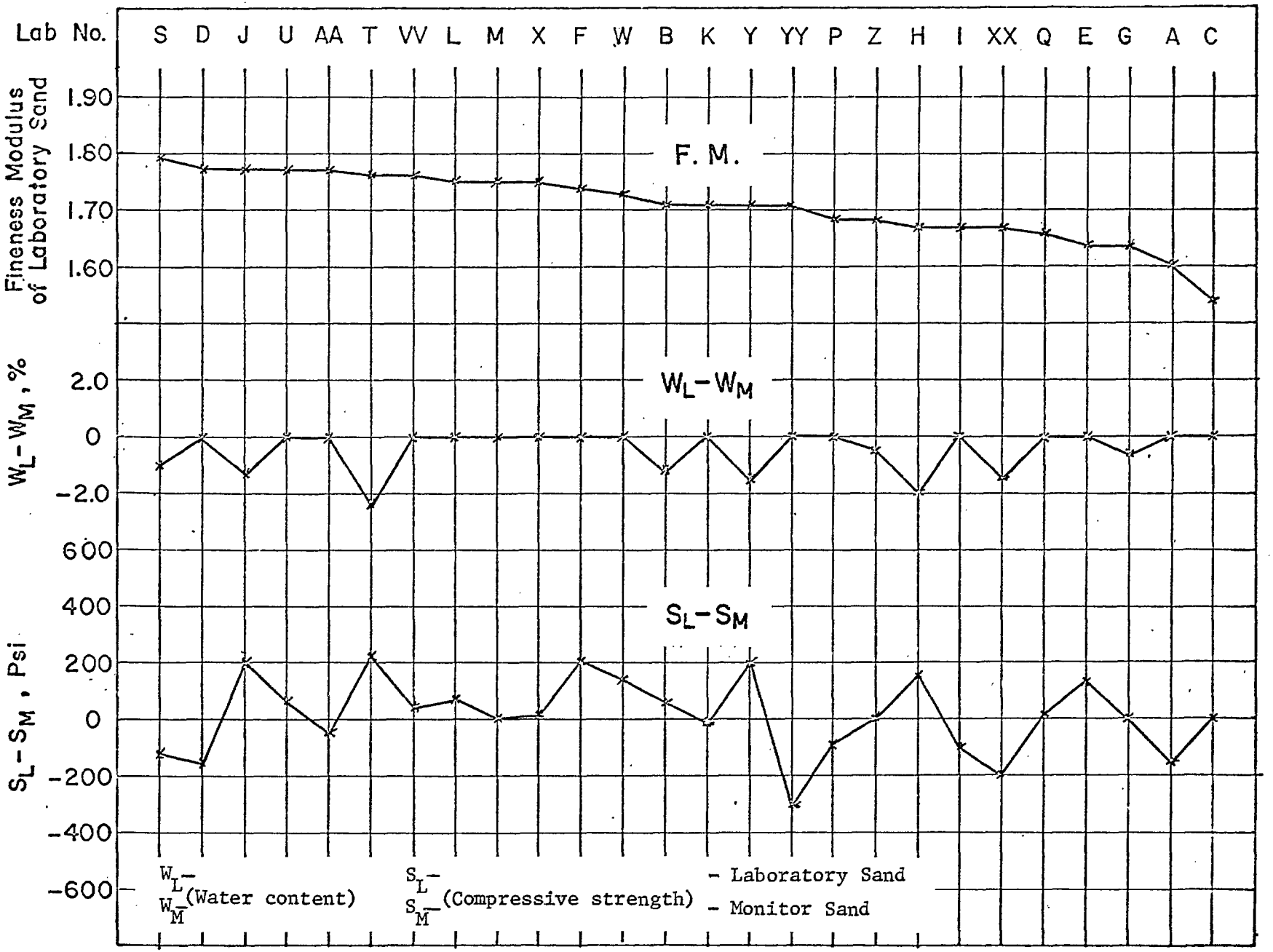

Fig. 8 —Effect of Sand Grading on Water Requirement and Compressive Strength of Mortar
(CSA Cement Sample No. 18)

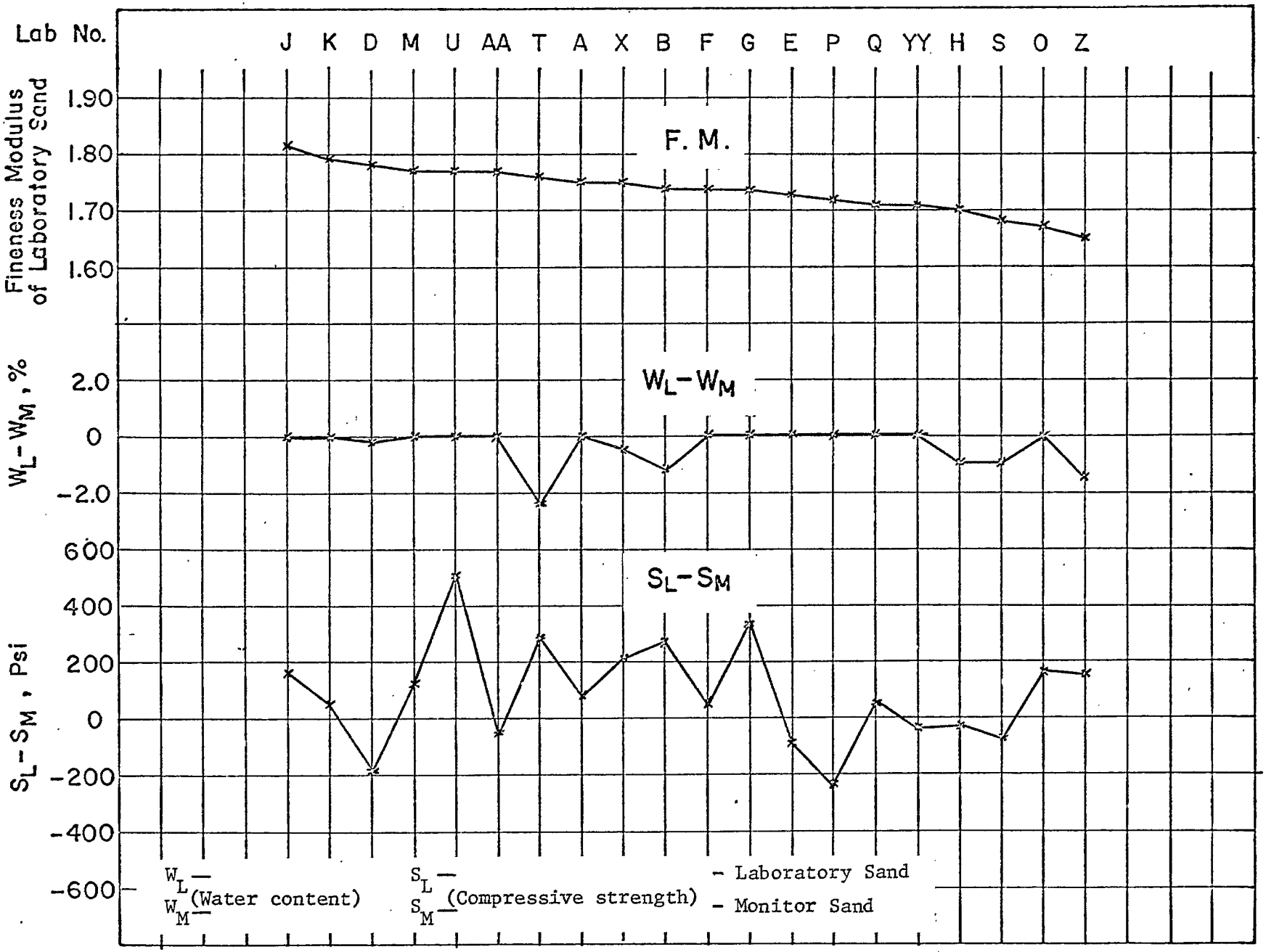

Fig. 9 —Effect of Sand Grading on Water Requirement and Compressive Strength of Mortar
(CSA Cement Sample No. 19)

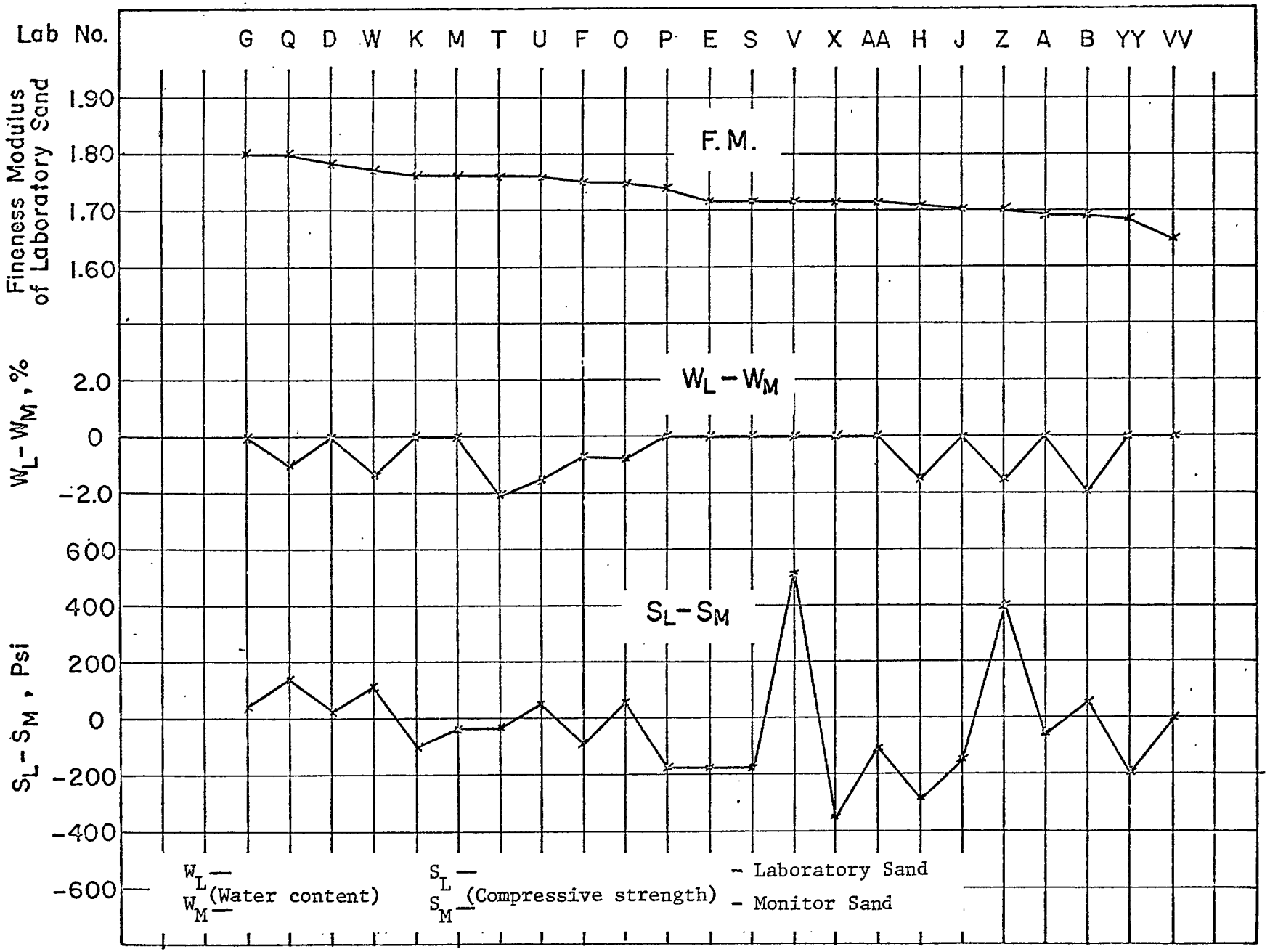

Fig.10 —Effect of Sand Grading on Water Requirement and Compressive Strength of Mortar
(CSA Cement Sample No. 20)

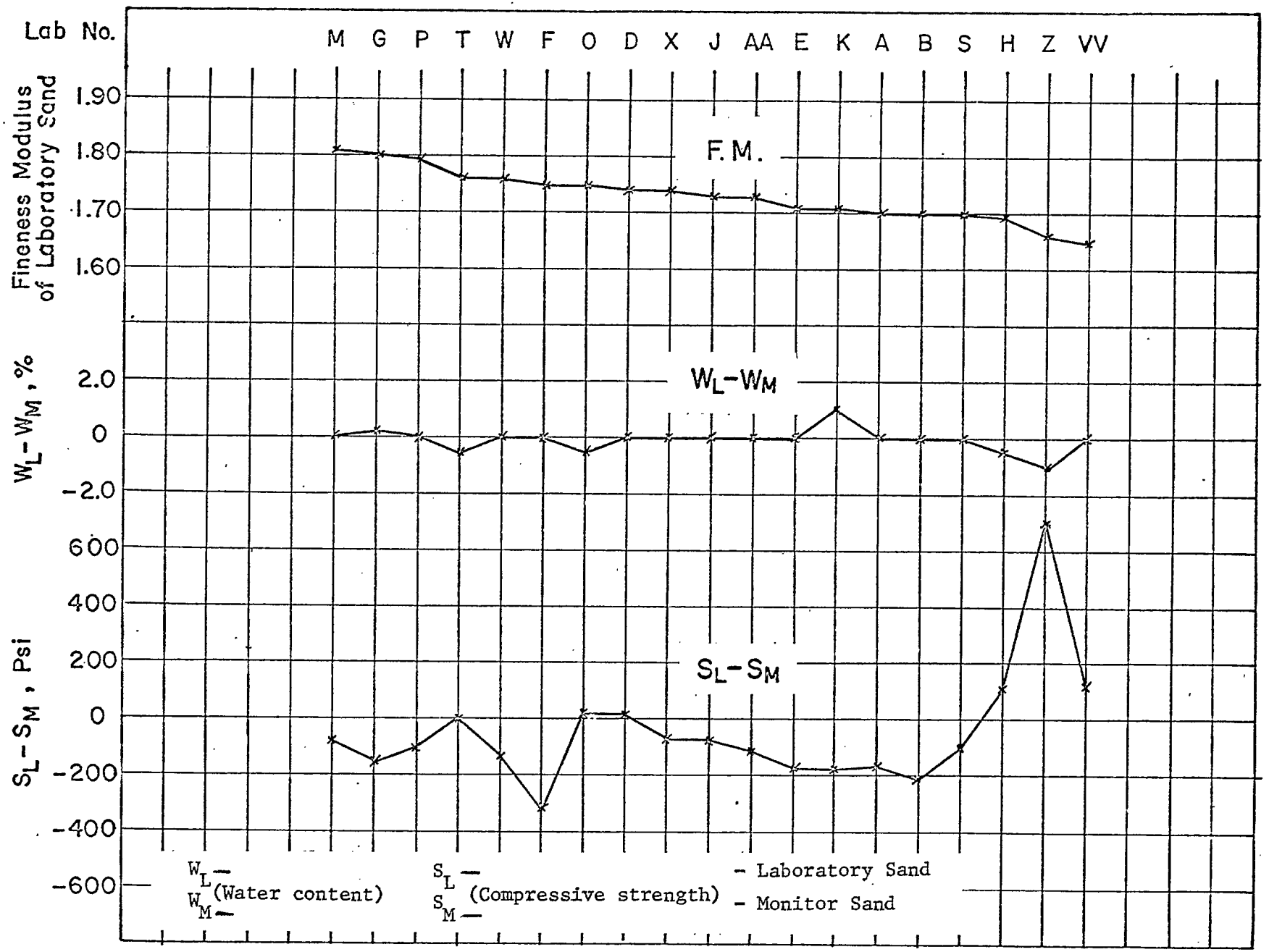

Fig. 11 — Effect of Sand Grading on Water Requirement and Compressive Strength of Mortar
(CSA Cement Sample No. 21)