4 December 1958

Errata Sheet

"TESTS OF SANDED GROUTS; INFLUENCE OF MANUFACTURED SANDS AND ADMIXTURES ON PUMPABILITY, AND EVALUATION OF A COLCRETE MIXER"

Technical Memorandum No. 6-419
Report 4
October 1958

1. Page 9, fig. 2. Substitute attached fig. 2.

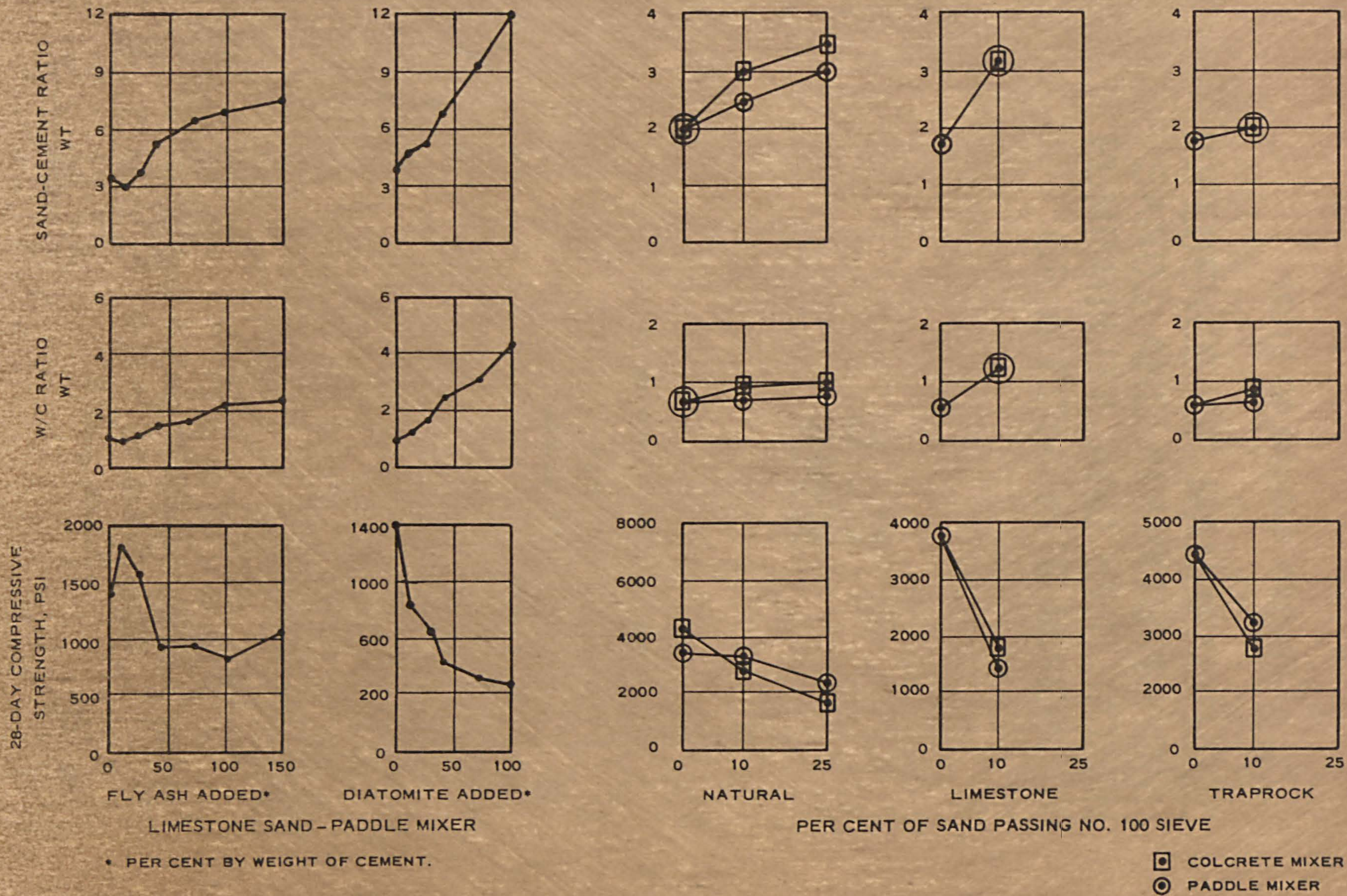

Fig. 2. Water-cement and sand-cement ratios, and compressive strength of the grout mixtures

TESTS OF SANDED GROUTS

INFLUENCE OF MANUFACTURED SANDS AND ADMIXTURES ON PUMPABILITY, AND EVALUATION OF A COLCRETE MIXER

TECHNICAL MEMORANDUM NO. 6-419

Report 4

October 1958

U. S. Army Engineer Waterways Experiment Station

CORPS OF ENGINEERS

Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

FOREWORD

This report on a single phase of a continuing investigation of sanded grouts is for information only. Any application of the test results reported herein by field installations of the Corps of Engineers that does not conform with approved field practice must be approved by the Chief of Engineers.

The contents of this report are not for advertising, publication, or promotional purposes.

PREFACE

The authority for this investigation was contained in first indorsement, dated 31 August 1955, to a letter from the Waterways Experiment Station to the Office, Chief of Engineers, dated 25 August 1955, subject "Sanded-grout Program for Fiscal Year 1956." The work was performed in connection with Civil Works Investigations Item No. CW 550 "Grouting Research - Concrete Dam Foundations."

The investigation was conducted by personnel of the Concrete Division, Waterways Experiment Station, under the supervision of Messrs. Thomas B. Kennedy, James M. Polatty, William O. Tynes, and Ralph A. Bendinelli. This report was prepared by Mr. Bendinelli.

The method of examination for the presence of clumps of cement grains in neat-cement grouts, described in Appendix A to this report, was developed by Mrs. Katharine Mather, Chief, Petrography Section, Concrete Division, Waterways Experiment Station.

CONTENTS

SUMMARY

The report describes two investigations: one was a continuation of studies reported previously to determine the maximum amount of sand that a sanded grout can contain and still be pumpable; the other was an evaluation of a new type of grout mixer, the colcrete, which is a double-drum, rapid mixing device designed especially for grouting work.

In the pumpability study, a manufactured limestone sand was used in the grout to which was added various amounts of two noncementitious mineral admixtures, fly ash and diatomite. It was found possible to pump grout containing 3 parts sand to 1 of cement when fly ash in the amount of 11% of the weight of the cement was added, and 7.5 parts sand when the percentage of fly ash was increased to 150. The addition of 11% diatomite made possible the pumping of 4.5 parts of sand, and of 100% diatomite permitted pumping 12 parts of sand. However, the higher water-cement ratios of the grouts containing diatomite resulted in increased setting time and lower compressive strength compared to the grouts containing fly ash.

The colcrete mixer was evaluated by comparing the pumpability of mixtures containing a natural and two manufactured sands prepared in it with that of identical mixtures prepared in a conventional paddle mixer. Also the physical properties of neat-cement grouts mixed in the two mixers were compared, and the effect of intermittent agitation on identical grouts mixed in the two mixers was studied to learn the influence on the physical properties of the sanded grouts and whether the colcrete- or paddle-mixed grout would remain pumpable the longer under the same conditions.

The maximum quantities of natural, limestone, and traprock sand found pumpable when colcrete-mixed were about the same as could be pumped in paddle-mixed grouts. Tests of the neat-cement grouts mixed for various lengths of time revealed only minor differences in the physical properties of samples from the two mixers. These grouts were also examined microscopically for clumping of cement grains, and the colcrete-mixed grouts were found to contain fewer clumps in less mixing time. The intermittent-agitation studies showed that the colcrete-mixed grouts remained pumpable for one-half hour and the paddle-mixed grouts for one hour under the same mixer-operation schedule.

On the basis of these tests it is believed that the colcrete mixer might be adaptable to a variety of small or medium-sized grout jobs. It mixes grout in about half the time that the conventional mixer requires, and could be modified to produce large quantities of neat grout. It may be used as a low-pressure pump for discharging grout to a distance of about 150 ft.

TESTS OF SANDED GROUTS

INFLUENCE OF MANUFACTURED SANDS AND ADMIXTURES ON PUMPABILITY, AND EVALUATION OF A COLCRETE MIXER

PART I: INTRODUCTION

Previous Reports

1. Three reports have previously been issued on phases of the comprehensive investigation of sanded grouts.* The first and second reports described the physical properties and pumpability of grouts containing natural sands. The third report described the physical properties and pumpabilities of grouts containing manufactured limestone and traprock sands. The sands contained no material larger than the No. 16 sieve size. Several percentages of sand finer than the No. 100 sieve size and/or various chemical or mineral admixtures were added to the grouts.

Purposes and Scope of This Phase

2. This phase (phase IV) of the investigation comprised two parts: the first was a continuation of the work described in Report 3 to determine the limits of pumpability of manufactured-sand grouts with varying percentages of mineral admixtures; the second was an evaluation of a new type of mixer known as the colcrete mixer.** This evaluation included: (a) tests to determine the mixer's ability to produce pumpable grouts using a natural and two manufactured sands; (b) comparison of the physical properties of identical neat-cement grouts mixed for various time intervals in the colcrete and conventional paddle mixers; and (c) a study of the effect of prolonged intermittent agitation on the physical properties of similar sanded grouts mixed in the two mixers.

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* Report No. 1, <u>Influence of Chemicals and Mineral Fines on Pumpability,</u> October 1955; Report No. 2, <u>Influence of Sand Grading and Addition of Mineral Fines on Pumpability,</u> October 1955; and Report No. 3, <u>Influence of Grading and Specific Gravity of Manufactured Sands on Pumpability,</u> February 1957.

** This mixer was referred to in Report 3 as the Colgrout mixer.

PART II: MATERIALS, EQUIPMENT, AND TEST PROCEDURES

Materials

Cement

3. A type II cement from Birmingham, Alabama, was used in these tests. Chemical and physical characteristics of the cement are as follows:

Chemical Data, %	
S_1O_2	22.5
Al_2O_3	4.7
Fe_2O_3	3.5
CaO	62.4
MgO	3.1
SO_3	1.5
Na_2O	0.21
$V_{-2}O$	0.53
Total alkalies as Na_2O	0.56
Loss on ignition	0.68
Insoluble residue	0.30
C_3S	42
C_2S	33
C_4AF	11
$CaSO_4$	3

Physical Data	
Fineness, air permeability, sq cm/g	3095
Soundness, autoclave, %	0.11
Time of setting, Gilmore	
Initial, hr:min	3:35
Final, hr:min	5:05
Compressive strength, psi	
3-day	1890
7-day	3325
28-day	5525
Air content of mortar, %	3.4

Sands

4. Three sands were used in this phase of the investigation: a natural siliceous concrete sand from the same source in Mississippi as that used in the work described in Reports 1 and 2; a manufactured limestone sand from the same source near Nashville, Tennessee, and a manufactured traprock sand from the same Connecticut source as similar sands used in the work covered in Report 3.

5. Each of the sands was divided into three groups on the basis of the amount of material finer than the No. 100 sieve size. These groups were: A, nominal 0% finer than the No. 100 sieve size; B, 10% finer; and C, 25% finer. The grading of each group was as follows:

Sieve No.	Gradings, Cumulative % Passing A	B	C
16	99 ± 1	99 ± 1	99 ± 1
30	67 ± 5	70 ± 5	75 ± 5
50	22 ± 5	30 ± 5	41 ± 5
100	0 ± 2	10 ± 1	25 ± 2

6. The percentages of flat and elongated particles determined for the No. 30 and No. 50 sieve fraction of each of the three sands were as follows:

Determined by	Natural No. 30	Natural No. 50	Traprock No. 30	Traprock No. 50	Limestone No. 30	Limestone No. 50
Operator 1	1	-	5	---	3	2
Operator 2	0	-	7	4	5	4
Operator 3	Trace	1	6	7	5	6
Average, %	1	1	6	3.7	4.3	4

7. The physical properties of the sands were the same as those reported in Reports 1 and 3 and are not repeated here.

Mineral admixtures

8. Diatomite and fly ash were used as mineral admixtures and were from the same sources as those used in the work described in Report 2, and had the same chemical and physical properties.

Combinations of materials used

9. The grout mixtures used in these tests consisted of the following materials in combination with water and type II portland cement:

Type of Sand	Sand Gradation	Type of Admixture	% of Admixture by wt of Cement
Limestone	B	Diatomite	11, 25, 43, 67, 100, 150
Limestone	B	Fly ash	11, 25, 43, 67, 100
Natural	A	None	None
Natural	B	None	None
Natural	C	None	None
Traprock	B	None	None
Limestone	B	None	None
None*	None	None	None

* This was a neat-cement grout mixture that was prepared using the same water-cement ratio used in the mixture of the last-listed sand grout.

Equipment

Mixers, pump, and circulating system

10. The paddle mixer, pump, and circulating system were described in Report 1 of this series.

11. The colcrete mixer is reputed to produce a more stable, fluid, lumpfree grout than the paddle mixer, through its centrifugal and high-speed mixing.* It is manufactured by Colcrete Limited, Gun Lane Strood, Rochester, Kent, England. The mixer used in this investigation was a wheel-mounted, double-drum, Mark III model. Tests were first made with this mixer in phase III of the investigation but were inconclusive owing, according to the American representative of the company, to its being underpowered. For the phase IV tests, the original 2-cylinder motor used to drive the two mixing units was replaced with a new 4-cylinder, Wisconsin, model VG4D motor. The colcrete mixer is operated as follows: The left-hand or first mixing unit is charged with cement and water which fall through the open, cone-shaped bottom of the unit into a modified centrifugal pump located immediately beneath. The pump rotor turns, circulating the neat grout back into the upper part of the mixing unit on a tangent. At the end of a specified mixing time, this grout is transferred to the right-hand or second, somewhat larger mixing unit by means of a quick-opening valve and transfer hose. Sand is added to the neat grout in the second and larger mixing unit, and the mixture is mixed at rates varying from 1800 rpm when both units contain approximately 2 gal of water each to 1600 rpm for the second specified period of mixing. The manufacturer's recommended mixing times are 15 sec for the first unit and 10 sec for the second unit.

12. Prior to the tests reported herein, the mixer had been used by the Sacramento District in grouting work at Folsom Dam, California. To improve its ability to mix neat grout and to increase its capacity, the Sacramento District had replaced the smooth rotor of the sand drum with a slotted rotor to increase mixing speed and discharge pressure. In addition, the left drum, loading tables, and operating handles were modified (see fig. 1). For the evaluation tests, the smooth rotor was put back on the mixer but it was not necessary to eliminate the other modifications mentioned above.

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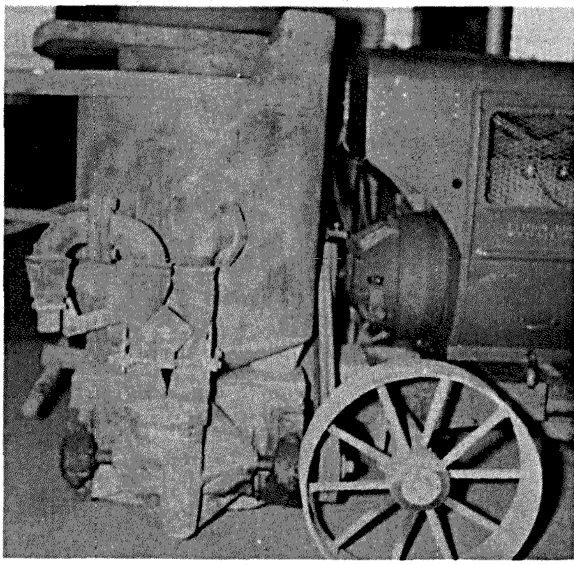
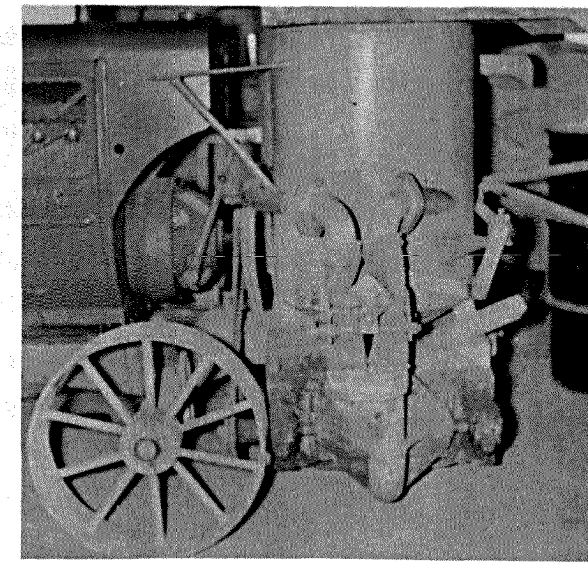
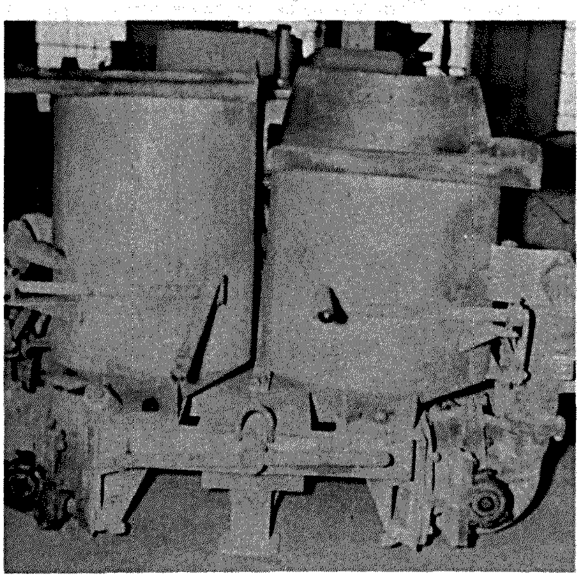
* See Report on the Use of Colcrete Grout Mixers at Folsom Dam, U. S. Army Engineer District, Sacramento, CE, February 1955. (Limited to official use of Corps of Engineers offices only.)



Right side



Left side



Front

Fig. 1. Colcrete mixer as modified with left-hand drum raised 12 in.; loading tables turned to front; and control handles lowered to clear tables

Maintenance

13. The following maintenance was required for the grout pump and the paddle and colcrete mixers during mixing and pumping operations:

a. Grout pump, in approximately 62 hr of operation, required:

(1) Two 3/4-in. pipe-hose adaptors at pump discharge.

(2) Two sets of rubber valve seats (four to a set).

(3) Two goose-neck valves (connection between pump and hose).

(4) One piston rod.

(5) One main line cutoff valve.

b. Paddle mixer, in approximately 6 hr of operation, required:

(1) One hose connection (bypass discharge into mixer).

(2) One quick-opening valve (mixer discharge).

c. Colcrete mixer, in approximately 5 hr of operation, required:

(1) One transfer hose (connecting mixing units).

(2) One pair rubber grout seals.

Test Procedures

14. For the pumpability tests conducted as a continuation of the tests described in Report 3, the paddle mixer was used to mix grouts containing limestone sand (gradation B) and various amounts of fly ash or diatomite (see paragraph 9). The tests consisted in pumping the grout mixtures through 200 ft of 3/4-in. hose arranged with a 13-ft vertical loop adjacent to the pump and the remainder coiled on a 5-ft radius at pump level. Pumpability was judged by the ability of the grout to resume circulation after a planned 15-min interruption in pumping. This apparatus and criterion were also used to evaluate the colcrete mixer's ability to produce pumpable grouts.

15. For the second part of the colcrete evaluation study, the investigation of the effects of various mixing times on grout properties, a neat-cement grout was mixed in the cement-water drum of the colcrete and a like grout was mixed in the single drum of the paddle mixer; samples were secured from each mixer at various time intervals and tested. For the third part of the evaluation study, determination of the effect of prolonged agitation on similar sand-grouts mixed in the two mixers, the mixers were operated at brief intervals to provide the minimum amount of intermittent agitation that would keep the grout materials fully in suspension and samples were obtained at scheduled periods for testing.

16. All the test methods employed in the study of the grout

mixtures, including those for determining consistency, bleeding, time of set, and compressive strength, were described in Reports 1 and 2. The microscopic examination mentioned herein for determining the presence of clumps of grains of cement in neat-grout mixtures is described in detail in Appendix A to this report.

PART III: DISCUSSION OF TEST RESULTS

Pumpability and Physical Properties of Manufactured-sand Grouts Containing Mineral Admixtures

17. The water-cement and sand-cement ratios and 28-day compressive strengths of the grout mixtures containing the maximum quantity of the limestone sand (gradation B) plus various amounts of the two mineral admixtures that could be pumped after being mixed in the paddle mixer are plotted in fig. 2. Results of the pumping and laboratory tests are summarized in table 1. Each value in the table represents an average of three tests at the amount of sand shown for each combination of materials. In the column headed "Proportion by Weight" the values for "Water" are also the water-cement ratios, and the values for "Cement" are the actual weights of portland cement in the mixtures and do not include the weights of the fly ash or diatomite.

Sand-carrying capacity

18. The data in table 1 show that when fly ash or diatomite was added to grouts containing limestone sand of gradation B, the sand-carrying capacity of the grouts was greater in all instances than that shown in Reports 2 and 3 for grouts containing the same percentages of the two admixtures but made with natural and limestone sands of gradation A. When the amount of diatomite added was equal in weight to the cement, it was possible to pump 12 parts of sand as compared to 7 parts when fly ash was equal to the cement. This greater sand-carrying capacity of the grout containing diatomite is attributed to the fineness (Blaine) of the diatomite which was 20,300 cm^2 per g as compared to 4055 cm^2 per g for the fly ash. When the fly ash was increased to 1.5 times the weight of the cement, 7.5 parts of sand were found to be pumpable.

Compressive strength, bleeding, and setting time

19. In the grouts containing fly ash, the water-cement ratio increased from 1.03 at 11% fly ash to 2.10 for 150% fly ash. The 28-day compressive strength was 1775 psi with 11% fly ash, 820 psi with amount of fly ash equal in weight to amount of cement, and 1025 psi with 150% fly ash. The bleeding of the 820-psi grout was 1.6% compared to 0.8% for the

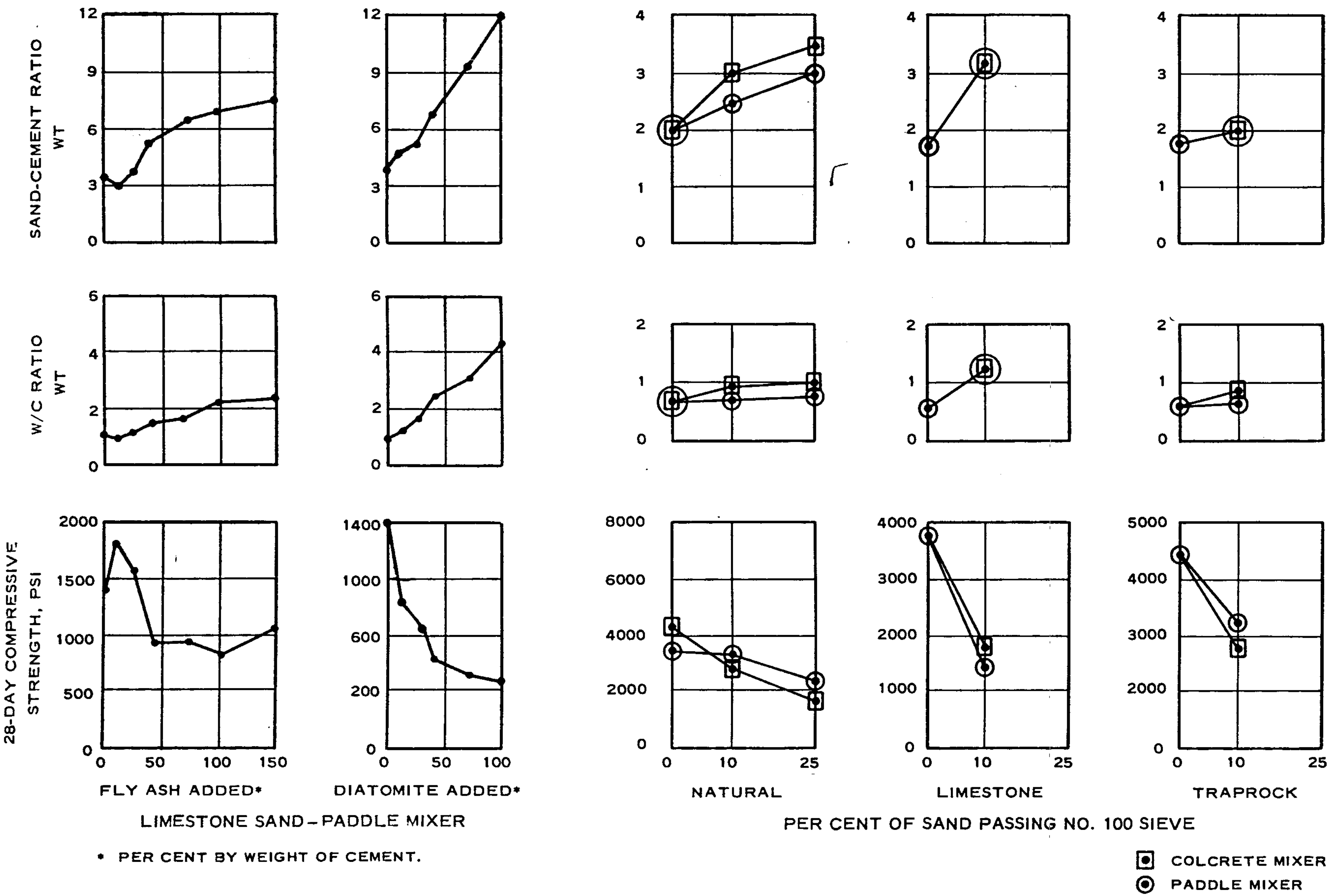


Fig. 2. Water-cement and sand-cement ratios, and compressive strength of the grout mixtures

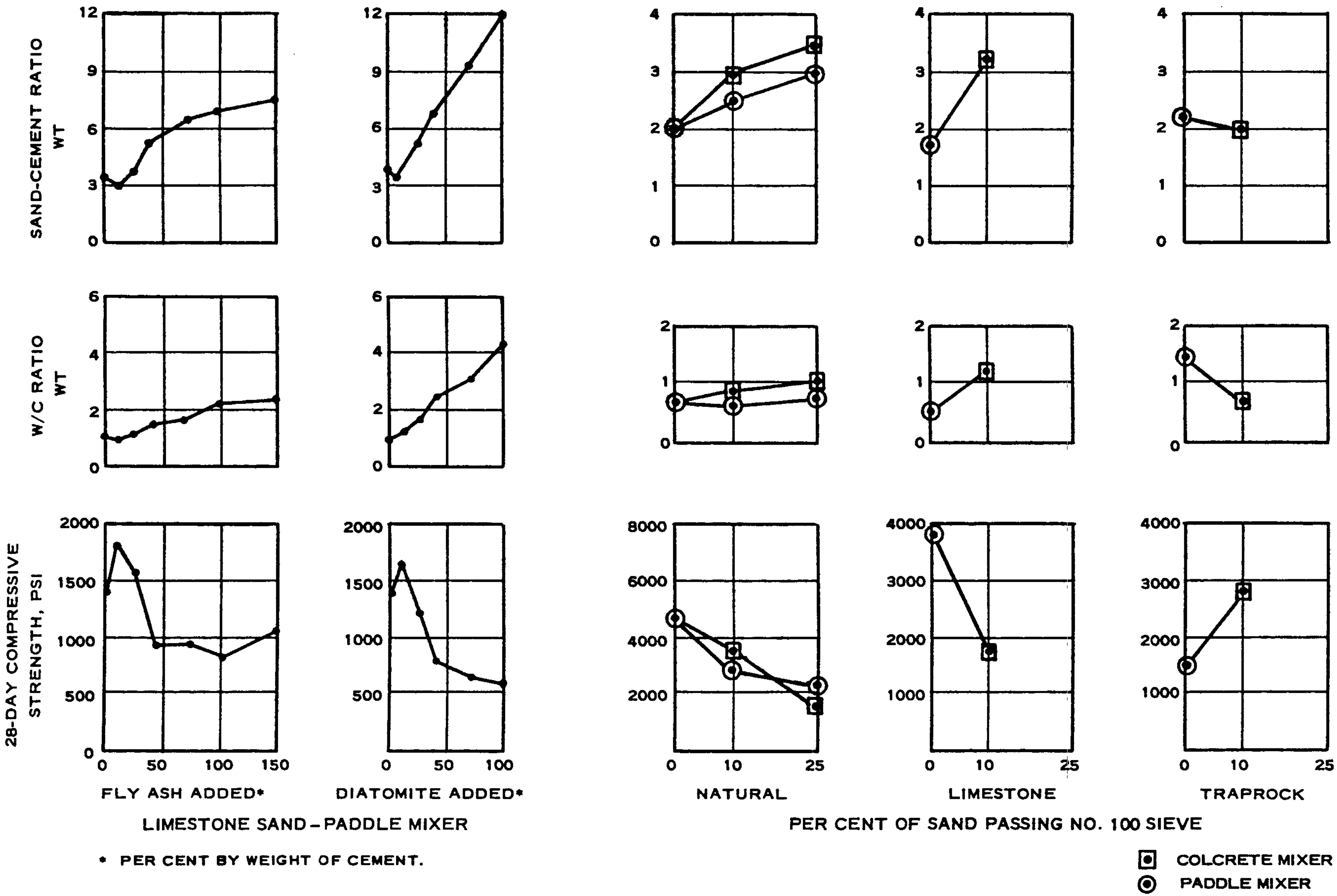


Fig. 2. Water-cement and sand-cement ratios, and compressive strength of the grout mixtures

1025-psi grout. The increase in strength of the 150% fly ash grout over that of the grout containing 100% fly ash appears to be a result of the lower bleeding of the former.

20. In the grouts containing diatomite, the water-cement ratio increased from 1.54 at 11% diatomite to 4.17 when the diatomite equaled the cement. The 28-day compressive strength was 805 psi with 11% diatomite and 255 psi at 100% diatomite. The data obtained in these tests showed similar trends in pumpability, strength, bleeding, and time of set to those shown by the data on grouts containing diatomite and fly ash in Reports 2 and 3.

Colcrete Mixer

Preliminary mixing-time tests

21. A preliminary series of tests was conducted to check the mixing times recommended by the manufacturer for each drum. In the tests of the sand drum, the recommended mixing time of 10 sec was found to be only about a third of the time required to eliminate a "sand-balling" condition that occurred when the drum was being charged with sand. The size and number of sand balls appeared to vary with the sand gradation, its free moisture content, the water-cement ratio of the mixture, and the size of the batch. Dry sands and sands having free moisture contents of 2% or less appeared to produce fewer and smaller sand balls. For these preliminary tests, the grout mixtures contained natural sands with 100% passing the No. 16 sieve size and 0 to 25% passing the No. 100 sieve size. In most cases when the water-cement ratios were increased to a point where the sand-balling was eliminated in the 10-sec mixing period, the grouts were too wet and thin to be pumpable.

22. The manufacturer's recommended mixing time of 15 sec for the cement-water drum appeared to be adequate on the basis of results of microscopic examinations of the grout described in Appendix A. However, as discussed above, the mixing time for the sand drum had to be increased to approximately 30 sec before adequate mixing was obtained. This increased mixing time necessitated slightly higher water contents than normally required for the 135 ± 15 degree torque consistency at which pumping was

begun. Difficulty was experienced in adjusting water contents to insure repeatability in the consistency of a given grout mixture. This apparent sensitivity of grout water contents is probably a result of fluctuations in rpm of the mixer caused by the sand balls that formed during the mixing operation.

Pumpability of natural and manufactured sand grouts

23. The limits of pumpability of the grouts containing the natural sand with A, B, and C gradations, and the traprock and limestone B-gradation sands, mixed in the colcrete mixer, are also shown in fig. 2 and table 1.

24. Natural sand. Examination of table 1 indicates that as the amount of natural sand passing the No. 100 sieve was increased from 0 to 25%, the quantity of sand that could be pumped increased 1.5 parts by weight. In the pumping tests reported in Report 2, it was found possible to increase the amount of sand in the natural sand grouts mixed in the paddle mixer by 1.0 parts when the minus-100 fines were increased from 0 to 25%. It is believed that the increase of 0.5 parts of sand in the pumpable colcrete-mixed grouts over that in the pumpable paddle-mixed grouts was mostly due to the priming of the colcrete mixer for each batch with a neat-cement grout. This priming was done on the recommendation of the manufacturer. The paddle mixer was not similarly primed in the pumping tests described in Report 2. The water-cement ratios of the colcrete-mixed grouts increased with the added fines from 0.68 to 1.00 by weight, while the 28-day compressive strengths dropped from 4115 to 1910 psi.

25. Limestone and traprock sands. The quantities of limestone and traprock sands, both with 10% passing the No. 100 sieve, found to be pumpable after mixing in the colcrete mixer were 3.25 and 2.00 parts, respectively. These are the same quantities of these sands found pumpable for the paddle-mixed grouts (Report 3). Thus, the priming of the colcrete mixer did not affect the pumpability of these two manufactured sand grouts as it did that of the natural sand grouts. The 28-day compressive strengths of the colcrete-mixed grouts were 1650 psi for the limestone sand, and 276 psi for the traprock sand mixtures.

26. During the pumpability tests it was found possible to discharge the tested grouts directly from the mixer and at mixer level for a distance

of approximately 150 ft. Such a discharge distance makes the mixer suitable as a low-pressure pump. It can be used to good advantage in grouting riprap and other similar grouting work.

Effect of mixing time
on grout properties

27. Similar neat-cement grouts with a 1.10 water-cement ratio were mixed in both mixers. Mixing times of 7-1/2, 15, 30, 60, and 120 sec were used in mixing this grout in the cement-water drum only of the colcrete mixer as compared to 1, 2, 4, 8, and 16 min in the single drum of the paddle mixer. Samples were secured at the end of each mixing period and tested for torque, flow time through a small funnel, viscosity (Stormer), and bleeding. In addition, samples secured at the end of each mixing period were examined microscopically to determine whether clumps of cement grains were present and in what amounts in the grouts mixed in each mixer.

28. The torque, flow time, and viscosity tests revealed only slight differences between the colcrete- and paddle-mixed grouts at any time; see table 2. Bleeding continued at approximately the same rate and in about the same amounts for samples from both mixers.

29. The microscopic examinations disclosed that the colcrete mixer in a 15-sec mixing time produced less clumps of grains of cement than did the paddle mixer in a mixing period of 2 min. The type of mixing produced in the cement drum of the colcrete mixer appears to result in better dispersion of the cement than occurs in the paddle mixer when neat-cement grouts are being mixed.

Effect of intermittent
agitation on grout properties

30. A sand-grout mixture containing natural sand of gradation B and having a cement-sand ratio of 1:3 and a water-cement ratio of 0.9 by weight of cement was used in these tests. The grout was mixed in the colcrete mixer for the recommended 15-10 sec, after which the mixing was stopped and a sample was secured. Mixing was started again after 2 min and continued for 15 sec, and this 2-min-off-15-sec-on operating procedure was continued until the grout became too stiff to test. Samples were secured after 1/2, 5, and 15 min and at four 30-min intervals thereafter. A similar grout was tested in the paddle mixer under the same operating

procedures except that the first sample was taken after an initial mixing period of 2 min; thereafter samples were obtained at the same time intervals as the colcrete-mixed samples were.

31. Bleeding, flow, torque, time of set, and compressive strength tests were made on all samples and the data obtained are summarized in the following table. The data in this table show that with the exception of the torque consistencies only small differences existed between the physical properties of the grouts.

Properties of Natural Sand Grout, Water-cement Ratio 0.9, Cement-sand Ratio 1:30, after Prolonged Intermittent Agitation

Sampling Times*	Amb Temp F	Grout Temp F	Flow Cone Time sec	Torque deg	Bleeding in 1 hr %	Time of Set (Vicat) hr-min Initial	Final	Compressive Strength, psi 7-day	28-day
				Colcrete Mixer					
10 sec	80	81	14.0	115	5.4	4-45	6-45**	1165	2540
30 sec	80	82	14.2	128	3.2	4-35	6-45**	1300	2725
5 min	80	82	14.2	133	4.2	4-15	6-40**	1305	2740
15 min	80	82	14.2	150	4.6	4-05	6-20**	1250	2540
30 min	80	83	14.0	155	4.2	3-35	6-05**	1155	2425
60 min	81	83	14.8	202	1.7	3-15	5-35**	1090	2235
90 min	81	83	16.0	263	0.6	3-00	5-05**	910	2100
120 min	82	85	21.8	350	0.3	2-35	4-35**	1050	2125
				Paddle Mixer					
2 min	80	85	13.2	137	6.6	4-55	7-00**	1560	2690
5 min	80	85	13.2	138	7.2	5-00	6-55**	1630	2960
15 min	80	85	13.2	140	6.8	4-00	5-55**	1590	2665
30 min	80	85	13.4	143	7.0	3-45	5-40**	1425	2615
60 min	80	85	14.0	170	4.2	3-15	5-10**	1305	2215
90 min	82	86	14.8	205	1.1	2-45	4-40**	1170	2210
120 min	83	87	17.2	265	0.7	3-05	4-55**	1080	2125
150 min	84	88	20.3	333	0.6	3-35	4-25**	1290	2110
180 min	84	90	34.0	510	0.2	2-40	3-55**	1320	2325

* Times after mixing was started at which samples were obtained.
** Approximate.

32. The data tabulated above show that when the natural sand grout was mixed and then intermittently agitated in the colcrete mixer, it developed a torque of 350 degrees in 120 min, whereas the same grout developed a torque of only 265 degrees when mixed in the paddle mixer and agitated intermittently for the same length of time. The higher torque of the colcrete-mixed grout is reflected by an increase in temperature of

2 degrees in 1 hr as compared to no increase in the temperature of the paddle-mixed grout in the same period of time. The results of the torque consistency tests indicate that pumpable sand grouts subjected to intermittent agitation in the colcrete mixer would remain pumpable for approximately 3/4 hr as compared to approximately 1-1/2 hr in the paddle mixer. The bleeding was slight for all samples tested. The maximum 28-day compressive strengths of 2740 and 2960 psi were observed on specimens cast from grout secured at the end of 5 min from the colcrete and paddle mixers, respectively.

Advantages and disadvantages of colcrete mixer

33. One or a combination of the following advantages of the colcrete mixer may warrant its use on small or medium-sized grouting jobs:

- a. It requires only approximately half as long to mix a batch of grout as the paddle mixer.
- b. Large quantities of neat grouts can be mixed when the mixer is modified so that both drums can be operated as single, independent mixers.
- c. The mixer is mobile and compact.
- d. The mixer will discharge grout to a distance of approximately 150 ft at pump level.
- e. It can be used to good advantage in riprap grouting.
- f. Because of its discharge pressure of 20 psi, it can be used as a low-pressure pump.

34. The following disadvantages were observed in the tests of the colcrete mixer:

- a. It is somewhat more difficult to clean than a conventional mixer.
- b. It requires more care in operation.
- c. Slight changes in water content of mixtures result in considerable changes in their consistencies.
- d. Under sustained operations it would require more expense to maintain than a conventional (paddle) mixer.
- e. Grout left in running mixer and agitated intermittently stiffens rapidly, becoming nonpumpable in about half the time of grout agitated in a conventional mixer.
- f. "Sand balling" of the grout in most cases is not eliminated until the last 15 sec of the 30-sec mixing time for the sand drum.

PART IV: CONCLUSIONS

35. Based on the tests made with the equipment, materials and techniques described in this report, and assuming that somewhat different results might be obtained using different equipment, the following conclusions appear warranted:

a. Both fly ash and diatomite were effective in promoting a marked increase in the pumpability of manufactured limestone sand that had a nominal 10% passing the No. 100 sieve. Grouts with a ratio of 1 part of portland cement to 7.5 parts of sand were successfully pumped with the addition of 1.5 times as much fly ash as cement. With equal quantities of cement and diatomite, a mixture containing 12 parts of limestone sand to 1 part of cement was found to be pumpable.

b. The higher water-cement ratios of the grout containing the diatomite resulted in lengthened time of set and lower 28-day compressive strengths for this grout as compared to those of the grout containing the fly ash.

c. With the adjustment of recommended mixing time and increased water-cement ratios, approximately the same amounts of natural and manufactured sand grouts were found to be pumpable when mixed in the colcrete mixer as were found pumpable when mixed in the paddle mixer.

d. Bleeding was minor for all sand-grout mixtures, and no correlation was apparent between the bleeding and the pumpability. This same conclusion was reached in the work covered by Report 3.

e. Traprock sand fines were much less efficient than limestone in increasing pumpability, as had also been found to be the case in the work covered by Report 3.

f. The microscopic examinations of the neat-cement grouts conducted as a part of the time studies disclosed that the colcrete mixer produced neat-cement grouts containing fewer clumps of cement grains in less mixing time than the paddle mixer.

g. The colcrete mixer may be used to mix sand grouts for many varieties of jobs. With certain modifications it can be employed to produce large quantities of neat grout.

h. The colcrete mixer may be used as a low-pressure pump and will discharge grout to a distance of approximately 150 ft.

i. In the colcrete mixer, such variables as the size of batch, sand-moisture contents, water-cement and cement-sand ratios, and sand gradations, or a combination of these variables, resulted in varying numbers and sizes of sand balls which reduced the rpm's of the colcrete mixer during mixing.

j. Water contents of grouts are very sensitive to the vigorous type of mixing action produced by the colcrete mixer.

k. Pumpable sand grouts subjected to prolonged agitation in the colcrete mixer remained pumpable for approximately 1/2 hr as compared to 1 hr for the paddle mixer.

Table 1

Pumping and Laboratory Test Data for All Grout Mixtures

Sand		Maximum Proportions by wt of Pumpable Mixtures			Consistency				Line Pressure psi		Pump Speed Strokes per min		Discharge cu ft per hr		Grout Temp F	Time of Set hr		Bleeding %	Compressive Strength, psi	
		Sand	Water	Cement	Torque, deg Before*	Torque, deg After*	Flow Cone Sec Before*	Flow Cone Sec After*	Before*	After*	Before*	After*	Before*	After*		Initial†	Final		7-day	28-day
										Limestone Sand, Paddle Mixer										
	Parts by wt Fly Ash**																			
B	0.11	3.00	1.03	1.0	133	144	12.4	12.6	135	140	54	50	65	63	74	5	21††	1.5	1025	1775
B	0.25	3.75	1.18	1.0	124	149	12.4	12.5	135	140	59	53	66	64	75	4	20††	1.1	800	1515
B	0.43	5.00	1.51	1.0	129	158	14.1	14.5	135	140	59	47	68	64	77	4	20††	1.7	435	925
B	0.67	6.25	1.83	1.0	124	155	14.2	14.5	135	140	57	55	72	70	78	4	20††	1.4	360	840
B	1.00	7.00	2.02	1.0	138	156	14.6	15.5	140	140	57	57	70	71	78	4	23	1.6	345	820
B	1.50	7.50	2.10	1.0	132	149	13.7	14.3	140	140	55	55	66	66	79	3	23	0.8	440	1025
	Parts by wt Diatomite**																			
B	0.11	4.50	1.54	1.0	136	149	12.3	12.4	135	140	63	62	72	74	73	4	19††	1.7	355	805
B	0.25	5.00	1.93	1.0	140	168	12.5	13.0	135	140	63	60	77	76	70	4	32††	1.1	200	625
B	0.43	7.25	2.44	1.0	140	172	12.8	12.5	135	140	65	65	70	70	70	4	37††	0.9	120	395
B	0.67	9.25	3.18	1.0	135	180	12.0	12.4	140	140	66	63	78	78	71	3	32††	0.7	80	330
B	1.00	12.00	4.17	1.0	135	180	11.9	12.7	138	138	66	64	80	78	74	3	82††	0.6	75	255
										Natural Sand, Colcrete Mixer										
	Sand, % Passing No. 100 Sieve																			
A	0	2.00	0.68	1.0	132	161	12.2	13.0	150	163	64	55	74	65	88	3	9††	1.4	2095	4115
B	10	3.00	0.90	1.0	133	168	12.5	13.8	160	160	59	50	72	66	90	2	17††	1.9	1310	2625
C	25	3.50	1.00	1.0	132	165	12.5	14.0	160	160	49	45	67	62	86	2	18††	4.1	890	1910
										Limestone Sand, Colcrete Mixer										
B	10	3.25	1.10	1.0	133	172	12.9	13.3	160	160	61	55	71	68	86	1	17††	2.0	985	1650
										Traprock Sand, Colcrete Mixer										
B	10	2.00	0.82	1.0	125	168	12.0	12.7	160	160	64	61	71	71	89	4	9††	1.3	1460	2765

* Before or after 15-min interruption in pumping.
** Using a sand with a nominal 10 per cent passing the No. 100 sieve.
† Set after hour shown.
†† Set prior to hour shown.

Table 2

Comparison of the Physical Properties of Grout Mixtures Mixed for Various Times in Both the Colcrete and Paddle Mixers

Mixture: Neat-cement Grout, Water-cement Ratio 1.10

Mixing Time	Amb Temp F	Grout Temp F	Stormer Time of 100 Rev sec		Flow Time Glass Funnel sec	Torque deg	Bleeding, %, at Intervals Indicated after Mixing in min (hr in Parentheses)											
			Imme-diately after Mixing	3 min Later			15 (1/4)	30 (1/2)	45 (3/4)	60 (1)	75 (1-1/4)	90 (1-1/2)	105 (1-3/4)	120 (2)	135 (2-1/4)	150 (2-1/2)	165 (2-3/4)	180 (3)
Colcrete Mixer																		
7-1/2 sec	82	82	7	7-1/2	32	11	10.0	20.0	26.0	27.0	27.4	27.8	27.8	27.8	27.8	27.8	27.8	27.8
15 sec	82	84	7	7-1/2	31	12	5.0	11.4	18.0	24.2	31.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
30 sec	82	84	7	7	30	12	5.0	9.8	14.0	20.0	24.6	32.0	37.0	37.4	37.4	37.4	37.4	37.4
60 sec	83	84	7	7	29	13	6.6	12.4	15.6	22.4	26.4	35.4	38.0	38.0	38.0	38.0	38.0	38.0
120 sec	83	85	7	7	30	13	6.0	11.0	16.0	20.6	26.6	32.0	36.4	36.4	36.4	36.4	36.4	36.4
Paddle Mixer																		
1 min	80	84	7	8	30	14	6.2	11.4	16.4	25.0	30.0	31.0	31.0	31.4	31.4	31.4	31.4	31.4
2 min	80	85	7	7	30	13	4.0	7.6	13.0	15.0	20.0	25.4	32.6	35.0	35.6	35.8	35.8	35.8
4 min	81	85	7	7	30	13	5.0	9.0	13.4	17.0	22.0	26.4	35.0	35.2	35.2	35.2	35.2	35.2
8 min	81	85	7	7	29-1/2	13	5.2	10.0	13.6	18.0	23.4	34.6	35.4	35.4	35.4	35.4	35.4	35.4
16 min	82	86	7	7	29	13	4.0	9.4	12.4	17.4	24.0	33.0	33.6	33.6	33.6	33.6	33.6	33.6

APPENDIX A: MICROSCOPIC EXAMINATIONS OF GROUTS MIXED IN A PADDLE AND A COLCRETE MIXER

Materials

1. The proportions of the cement-water grouts examined and data on relevant physical tests of the cements are tabulated below. All three cements were Lone Star Type II from Birmingham, Alabama, and had been sieved over No. 16 sieve before they were used.

Mixer	Date	W-C Ratio Wt	Sp Surf (Blaine) sq cm/g	% Retained on No. 325 Sieve
Colcrete	4 Apr 56	0.65	3590	5.2
Paddle	26 Apr 56	0.65	3315	4.4
Both*	28 June 57	1.1	3243	Not made

* Both colcrete and paddle mixers.

Purpose of Examinations

2. The examinations were made to determine whether clumps of cement grains were present in grout mixed in either mixer. The Colgrout literature states that "The intensive shearing or rubbing action of high-speed mechanical mixing in Colcrete Mixers results in such complete dispersion and hydration of the cement that the subsequent addition of chemical wetting agents is ineffective." This statement implies that the action of the colcrete mixer should produce a grout in which all of the cement grains are separated from each other, and that a conventional paddle mixer would not produce such complete separation of the cement grains.

Examination Procedure

3. A preliminary trial on 30 March 1956 showed that sanded grouts could not be examined in transmitted light without the grout on the microscope slide being sheared in the process of making a sample thin enough to transmit light.

4. To determine whether colcrete-mixed and paddle-mixed grouts differed in the presence and abundance of clumps of cement grains required a

reproducible method of making specimens for examination that would minimize chances of breaking up any clumps that might exist. The grouts as they are mixed are thick; a drop placed on a microscope slide is opaque and does not run out to a transparent film when a cover glass is placed on it. Pressing down the cover glass or shearing out the drop would tend to break up clumps.

5. The grouts examined in 1956 were diluted with a solution of Methocel in water, by taking up 1.5 ml in a calibrated tube and adding it to 30 ml of Methocel solution in a dropper bottle. The bottle was capped and gently agitated by turning it end over end until some dispersion took place. Then a drop was withdrawn, placed on a clean slide and covered with a clean cover glass, and the specimen examined at a magnification of 200. To reduce the chances that the weight of the cover glass might break up aggregates of cement grains, and to establish a reasonable probability that fairly large clumps could be sampled in a specimen prepared in this way, it was required that a slide contain at least three individual grains of cement with maximum measured dimensions of 74 microns or more, before the presence or absence of clumps was considered significant. Samples of the dry cements were also examined. A little cement was placed on a slide, a few drops of Methocel solution added, and a cover glass applied. A few small clumps of small grains were found in the slide of RC-376, but they were less abundant and much smaller than the clumps in the grout.

6. The same techniques were used for the grouts examined in June 1957 as well as the same criteria for accepting or rejecting slides. However, the supply of Methocel solution on hand was not large enough to permit the same technique to be used with all 10 samples, and since it takes three days to prepare a clear Methocel solution, the dilution method was modified. Eight samples were diluted with Methocel; the other two were diluted with glycerol, which has a viscosity fairly similar to that of the Methocel solution. Since it was expected that the glycerol would dissolve the cement to some extent, glycerol was used for a sample in the middle of each series, the second sample of colcrete-mixed grout and the third sample of paddle-mixed grout. In both cases, the particle shapes of cement grains in the slide of the grout diluted with glycerol were rounder than the particle shape of grains in the preceding and following samples.

Results

7. Results of the examinations of cement-water grouts made in the two mixers at two different water-cement ratios are shown in tables A1 and A2.

Grouts with water-cement ratio of 0.65

8. The colcrete mixer produced grout in which the grains of cement were separated after 15 sec mixing. Groups of 2 or 3 grains each smaller than 1 micron were common in the grout mixed 7.5 sec; mixing times greater than 15 sec did not result in recognizable changes. The paddle mixer produced grout in which clumps of grains were found after 1, 2, 4, and 8 min mixing. The largest clumps were found in the 2-min samples; they decreased in number and size with longer mixing.

Grouts with water-cement ratio of 1.1

9. Clumps were less abundant in the grouts of higher water-cement ratio than in the grouts previously examined, but aggregations of a small number of relatively large grains were more common in the grout mixed 1 min in the paddle mixer than they were in the paddle-mixed grout of lower water-cement ratio. Clumps diminished with increased mixing time in the paddle mixer, up to the 16-min sample, which contained more clumps than any of the samples representing shorter mixing times. The colcrete-mixed grout contained some clumps in the sample mixed 7.5 sec; little change was noted between slides of grouts mixed 15 sec and 60 sec.

Table A1

Effects of Mixing Time on Neat-cement Grouts of 0.65 W/C Mixed in Paddle and Colcrete Mixers

W/C = 0.65; RC-376, 26 April 1956		W/C = 0.65; RC-330, 4 April 1956	
Mixing Time min	Paddle Mixer	Mixing Time sec	Colcrete Mixer
1	Clumps very abundant; in 50 mm of traverse, one 72 by 50μ, grains 6μ and less, one 50 by 40μ, grains 10μ and less, one 44 by 22μ, grains 4μ and less; several lines of 3 to 6 grains, about 10 by 2μ	7.5	Grains 4μ and less in maximum diameter tend to lie in strings in point contact. At 860x, groups of 2 to 3 grains smaller than 1μ are fairly common
2	Two slides contained larger clumps than were found in grout mixed 1, 4, or 8 min; one 720 by 425μ, one 290 by 135μ, 210 by 200μ, 145 by 85μ, and many smaller ones	15	One 50μ grain with an 8μ grain adhering to it. A few clumps of 2 or 3 grains smaller than 1μ. A few loose piles of 2 to 10μ grains in point contact
4	Fewer clumps than in grouts mixed 1 or 2 min; one 175 by 100μ, 80 by 60μ, 60 by 30μ, 35 by 35μ	30	Fewer strings and loose piles than in the 7.5-sec grout; comparable to the 15-sec grout; no consistent difference recognized
8	Fewer clumps than in grouts mixed shorter times, but some present. One 120 by 40μ of grains 30 by 30μ; one 60 by 40μ of grains 25 to 4μ	60	Like 30-sec samples

Note: Fineness of RC-376, 3315 sq cm/g (air permeability). Fineness of RC-330, 3590 sq cm/g.

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Table A2

Effects of Mixing Time on Neat-cement Grouts of 1.1 W/C Mixed in Paddle and Colcrete Mixers

RC-406; 28 June 1957

Mixing Time min	Paddle Mixer	Mixing Time sec	Colcrete Mixer
1	Clumps fairly abundant but usually made up of 2 to 4 fairly large grains; two largest clumps 82 by 51μ and 55 by 43μ; few clumps of many small grains like those found in grout of 0.65 W/C	7.5	Aggregations of 2 or 3 dust-sized grains fairly common. Largest clump 98 by 55μ. Most groups are many small and medium grains
2	Clumps as above; more made up of small grains than in the 1-min sample; in both, more isolated grains than grains in clumps. Maximum sizes 140 by 94μ, 101 by 43μ, 98 by 39μ	15	Fewer clumps of small and dust-sized particles than in previous slide. Accumulations of as many as 6 dust-sized grains are uncommon
4	Fewer groups of very minute grains than in two previous; maximum group sizes 176 by 58μ, 140 by 39μ, 90 by 78μ	30	Not much change here as compared to 15-sec mixing
8	Substantial reduction from 3 previous in large clumps made of large grains; some 4 by 4μ clumps made up of virtually unresolvable particles, two largest clumps 70 by 47μ and 62 by 55μ	60	Similar to previous; a few strings of medium-sized grains in point contact
16	Many more clumps in this slide than in any previous; no change in this slide 4 hr after it was first examined; second slide made 4 hr after first; similar but clumps of unresolvable particles less abundant. Groups range from 70 by 40μ down, made of very minute grains; unlike all previous slides	120	Less aggregation than in previous slides; a fine dispersion; occasionally 3 to 5 small grains in point contact

Note: Fineness of RC-406, 3243 sq cm/g (air permeability).