CORPS OF ENGINEERS, U. S. ARMY

TESTS OF SANDED GROUTS

REPORT NO. 3

INFLUENCE OF GRADING AND SPECIFIC GRAVITY OF MANUFACTURED SANDS ON PUMPABILITY

~~CWI ITEM NO. 550~~

GROUTING RESEARCH - CONCRETE DAM FOUNDATIONS

TECHNICAL MEMORANDUM NO. 6-419

CONDUCTED FOR

OFFICE OF THE CHIEF OF ENGINEERS

BY

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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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 to be used for advertising, publication, or promotional purposes.

PREFACE

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 Bendinelli. This report was prepared by Mr. Polatty.

CONTENTS

SUMMARY

The maximum amount of two types of manufactured sand having different specific gravities that could be pumped in a sand-cement grout was determined using sands with three degrees of fineness for each type as represented by the amount of material finer than the No. 100 sieve size. In addition, limits of pumpability were determined for grouts containing a sand with essentially no material finer than the No. 100 sieve, to which were added two fine noncementitious mineral admixtures in quantities of 11, 25, 43, 67, and 100 per cent by weight of the cement.

It was found possible to pump 1.75 parts of both limestone and traprock sand to 1.0 part of cement by weight when the sand contained no material finer than the No. 100 sieve size, and 7 parts of limestone sand and 2.25 parts of traprock sand to 1.0 of cement when 25 per cent of either sand was finer than the No. 100 sieve size. The addition of the noncementitious mineral fines (fly ash and loess) had almost the same effect on pumpability as the addition of the same amount of limestone fines.

The traprock fines were less efficient in increasing pumpability.

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PART I: INTRODUCTION

Previous Reports

1. Two reports have previously been issued on phases of the comprehensive investigation of sanded grouts.* These reports described the physical properties and pumpability of grouts containing natural sands. The sands contained no material coarser than the No. 16 sieve size, but several percentages of material finer than the No. 100 sieve size or various chemical or mineral admixtures were added to the grouts.

Purpose and Scope of This Phase

2. The original plan for this phase of the investigation of sanded grouts contemplated two parts. The purpose of the first part was to determine the maximum amount of manufactured limestone and traprock sands that can be incorporated in pumpable grout. The purpose of the second part was to evaluate the mixing properties of a Colgrout mixer.

3. As in the tests reported in Reports 1 and 2, the limits of pumpability were to be judged by pumping the mixtures through 200 ft of 3/4-in. hose arranged with a 13-ft vertical loop adjacent to the pump and the remainder of the hose coiled on a 5-ft radius at pump level. Pumpability was to be judged by the ability of the grout to resume circulation after a planned 15-min interruption in pumping.

4. In the first part of this phase, pumping tests were made of grouts containing the two types of manufactured sand of different specific

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* Waterways Experiment Station Technical Memorandum No. 6-419, Tests of Sanded Grouts; Report No. 1, Influence of Chemicals and Mineral Fines on Pumpability, October 1955, and Report No. 2, Influence of Sand Grading and Addition of Mineral Fines on Pumpability, October 1955.

gravities mentioned in paragraph 2. Then grouts made with three gradings of sand, nominal 0, 10, and 25 per cent finer than the No. 100 sieve size, were pump-tested. In addition, the effect on pumpability of adding various percentages of fly ash and loess to mixtures containing no sand finer than the No. 100 sieve size was studied.

5. The results of tests for the evaluation of the Colgrout mixer were inconclusive since no difference could be observed in its mixing action and that of the conventional paddle mixer. The American representative of the Colgrout Company stated that the Colgrout mixer used in this investigation was underpowered, and that the 14-bhp gasoline engine furnished with the mixer should be replaced with one of 19 hp. This has been done and it is planned to rerun the tests, but no test results are available at this time; therefore no data on the tests conducted on the Colgrout mixer are included in this report. The results obtained with the modified mixer will be incorporated in a later report.

PART II: MATERIALS, EQUIPMENT, AND TEST PROCEDURES

Materials

Cement

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

Chemical Data, %	
SiO_2	22.6
Al_2O_3	4.4
Fe_2O_3	3.9
CaO	63.1
MgO	3.0
SO_3	1.6
Na_2O	0.19
K_2O	0.58
Total alkalies as Na_2O	0.57
Loss on ignition	0.60
Insoluble residue	0.44
C_3S	45
C_2S	31
C_3A	5
C_4AF	12
$CaSO_4$	3

Physical Data	
Fineness, air permeability, sq cm/g	3590
Soundness, autoclave, %	0.10
Time of setting, Gillmore	
Initial, hr:min	5:30
Final, hr:min	8:00
Compressive strength, psi	
3-day	1745
7-day	2665
28-day	5140
Air content of mortar, %	8.8

Sands

7. The manufactured sands used consisted of a limestone from the vicinity of Nashville, Tennessee, and a traprock from New Haven, Connecticut.

8. The sand gradings were 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

9. The physical properties of the sands were:

	Limestone			Traprock		
	A	B	C	A	B	C
Specific gravity	2.67	2.67	2.62	2.91	2.90	2.90
Absorption, %	1.0	1.1	2.5	1.6	1.3	1.3
Soundness, magnesium sulfate,						
5 cycles, loss, %		10			2.2	
Mortar-making properties						
3-day strength, %		163			105	
7-day strength, %		158			121	
Flat and elongated particles, %						
No. 16 to 50 size		7			10	
No. 30 to 50 size		10			5	
Material passing No. 100 sieve						
Surface area, air permeability, sq cm/g		1145			470	
Passing No. 200 sieve, %		41			15	
Passing No. 325 sieve, %		35			5	

Mineral admixtures

10. Mineral fines, fly ash from Chicago, Illinois, and loess from the Vicksburg, Mississippi, area were used. Chemical and physical characteristics of these materials follow:

Physical Data

	Fly Ash	Loess
Specific gravity	2.55	2.59
Fineness, air permeability, sq cm/g		
Blaine	4055	1795
Fisher	4128	1930
Passing No. 200 sieve, %	95	97
Passing No. 325 sieve, %	93	96

(Continued)

Chemical Data, %

	Fly Ash	Loess
SiO_2	46.4	59.5
Al_2O_3	18.5	8.9
Fe_2O_3	18.2	3.2
CaO	6.5	7.4
MgO	1.6	3.9
SO_3	2.8	0.0
Na_2O	2.3	1.2
K_2O	2.1	2.4
Loss on ignition	1.2	13.0
Insoluble residue	66.5	73.3
Total carbon	0.7	2.6

Combinations of materials tested

11. The grouts used in the pumping tests consisted of the following combinations of materials:

a. Cement, water, and limestone sands of three gradations.

b. Cement, water, and limestone sand, none of which was finer than the No. 100 sieve size, with the addition of approximately 11, 25, 43, 67, and 100 per cent of both fly ash and loess based on the weight of the cement.

c. Cement, water, and traprock sand of three gradations.

d. Cement, water, and traprock sand, none of which was finer than the No. 100 sieve size, with the addition of both fly ash and loess in amounts of approximately 11, 25, 43, 67, and 100 per cent of the weight of the cement.

Equipment

Mixer, pump, and circulation system

12. The equipment used to mix, pump, and circulate the grout was described in Report 1 of this series.

Maintenance

13. In order to furnish an idea of the nature and extent of maintenance required when mixing and pumping sanded grouts containing

. manufactured sands, the following data are furnished:

a. Grout pump, in approximately 83 hours of operation, required:

   (1) Two rubber diaphragms in line to pressure gage.

   (2) One 3/4-in. pipe-hose adapter at pump discharge.

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

   (4) Two goose-neck valves (connections between pump and hose).

b. Mixer, in approximately 8 hours of operation, required two mixer motor brushes.

Test Procedures

14. All the test methods used 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.

PART III: TEST RESULTS AND DISCUSSION

Pumpability Tests with Manufactured Sands

Mixtures pumped

15. The 28-day compressive strength and the water-cement and sand-cement ratios of the grout mixtures containing the maximum quantity of sand that could be pumped are plotted on fig. 1. 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 value for "Water" is consequently also the water-cement ratio and the value for "Cement" is the actual weight of portland cement in the mixture and does not include the weight of fly ash or loess in the cases where they were used.

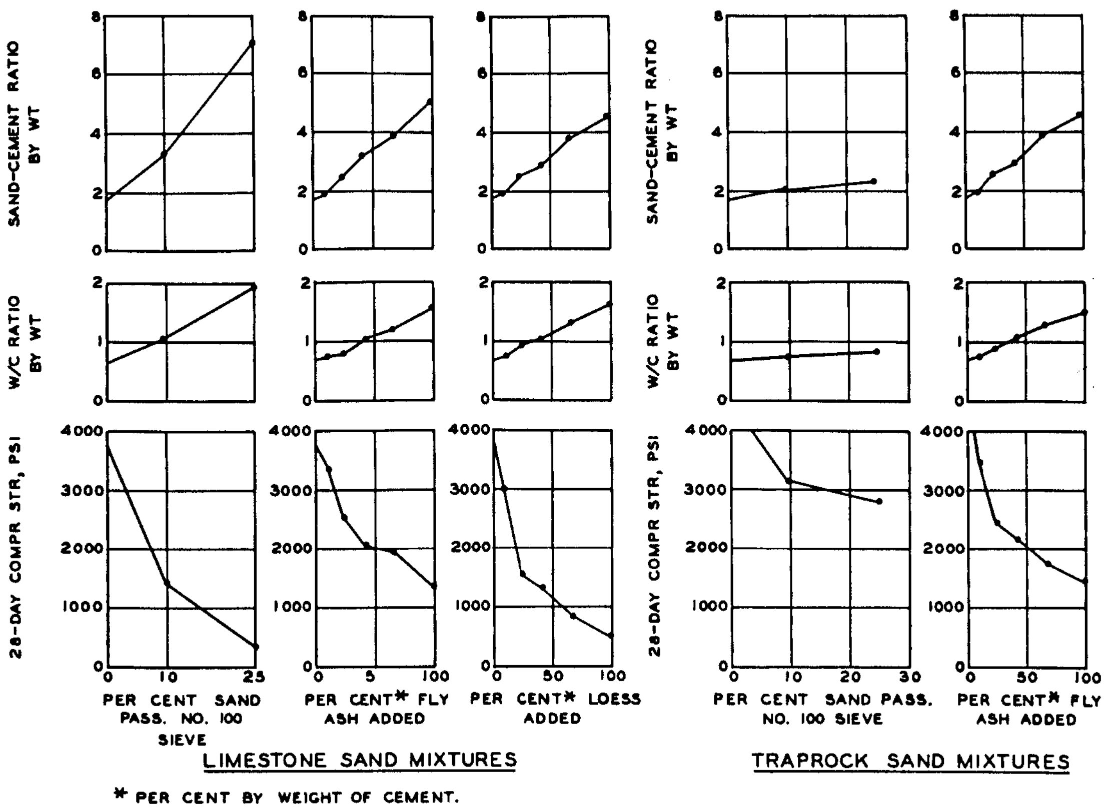

Fig. 1. Compressive strength, water-cement and sand-cement ratios of the grout mixtures

Limestone sand

16. The tests of grout mixtures containing limestone sand showed that:

a. An increase in the amount of sand finer than the No. 100 sieve size resulted in a large increase in the sand-carrying capacity of the mixtures.

b. When fly ash or loess were added to mixtures containing sand with basically no material finer than the No. 100 sieve size, the sand-carrying capacity of the grouts was increased. The effect on the sand-carrying capacity was not appreciably different for either of these admixtures although the specific surface of the fly ash is about twice that of the loess (paragraph 10).

17. It appears that the addition of limestone finer than the No. 100 sieve size is as effective in increasing the sand-carrying capacity of the grouts made with limestone sand as is the addition of fly ash or loess, although the fly ash and loess were considerably finer.

Traprock sand

18. As in the grouts made with limestone sand, an increase in the percentage of traprock sand finer than the No. 100 sieve size resulted in an increase in the total amount of sand that could be used in a pumpable grout. However, the increase in sand-carrying capacity was relatively small, especially when compared to that of the grouts made with limestone sand. The addition of traprock finer than the No. 100 sieve size was not as effective in promoting pumpability as was the limestone. The surface area of the traprock fines was much less than that of the limestone fines.

19. The addition of fly ash to the traprock sand with essentially no material finer than the No. 100 sieve size afforded similar results to those obtained in the limestone sand-fly ash tests.

Discussion of Results of Pumpability Tests

20. The amount of both limestone and traprock sand of grading A, with essentially no material finer than the No. 100 sieve size, that could be incorporated in pumpable grout was found to be 1.75 parts to

1.00 part of cement. The fact that identical amounts were found pumpable appears to eliminate the specific gravity (2.67 limestone, 2.91 traprock) as an element influencing pumpability in these tests. The fact that less traprock sand containing 10 and 25 per cent of material finer than the No. 100 sieve could be pumped than was the case with limestone sand appears to be a function of the relative surface area of the traprock and limestone fines. If the traprock fines had been as fine as the limestone fines, it is believed that the pumpability of the traprock sand would have compared more favorably with that of the limestone sand.

21. When the fines were supplied to the traprock sand of grading A by the addition of fly ash, there was little difference in the pumpability of the limestone and traprock sand grouts.

22. The surface texture of the limestone fines may also have helped promote pumpability because, although the limestone fines had a lower surface area value than the fly ash or loess, they appeared more efficient pound for pound than either fly ash or loess in promoting pumpability.

Discussion of Results of Physical Tests

23. No wide range was found in either the initial or final time of setting in or between the mixtures tested. It would appear that a slight increase occurred in those mixtures containing fly ash and loess as compared to those with no mineral admixture.

24. In general, the compressive strengths of all the mixtures containing similar materials were functions of their water content. The mixtures containing fly ash showed a slightly higher strength at 28 days than mixtures with comparable water contents without fly ash, probably owing to the pozzolanic action of the fly ash. As was to be expected, the mixtures containing traprock sand had a higher compressive strength than those with limestone sand.

25. Bleeding of all the mixtures was slight; however, the mixtures with traprock sand bled about twice as much as those with limestone sand. The addition of fly ash and loess appeared to reduce the bleeding

slightly in the limestone sand mixtures but did not have much effect in the traprock sand mixtures.

PART IV: CONCLUSIONS

26. These conclusions are based on the tests made with the equipment and materials described. Somewhat different results might be obtained with other equipment. Also, other mineral materials, because of their surface chemistry might, with similar granulometric characteristics, exhibit somewhat different properties when incorporated in portland-cement grouts.

27. The following conclusions appear warranted:

- a. Sands manufactured from limestone and traprock can be successfully used in sanded grouts.
- b. The specific gravity of the sand had little or no effect on the pumping characteristics of the grout.
- c. Both fly ash and loess were effective in promoting pumpability when used with sands deficient in material finer than the No. 100 sieve size.
- d. The limestone fines used in these tests, although having somewhat lower specific surface values than the fly ash or the loess, were pound for pound more efficient in promoting pumpability than those materials.
- e. Traprock fines, being relatively coarse, were not as efficient as fly ash or loess and were much less efficient than limestone in increasing sand-carrying capacity.
- f. Setting time appeared to be lengthened slightly by addition of fly ash and loess.
- g. Compressive strength varied with water content but that of the mixtures containing fly ash was slightly higher at 28 days.
- h. Bleeding was minor for all the mixtures.

Table 1

Pumping and Laboratory Test Data for All Grout Mixtures

Sand	Sand, % Passing No. 100 Sieve	Proportion by Weight: Sand	Proportion by Weight: Water	Proportion by Weight: Cement	Consistency: Torque, Deg: Before*	Torque, Deg: After*	Flow Cone, sec: Before*	Flow Cone, sec: After*	Line Pressure psi: Before*	Line Pressure psi: After*	Pump Speed Strokes per min: Before*	Pump Speed Strokes per min: After*	Discharge cu ft per hr: Before*	Discharge cu ft per hr: After*	Grout Temp F	Time of Set hr: Initial	Time of Set hr: Final	Bleeding %	Compressive Strength, psi: 7-day	Compressive Strength, psi: 28-day
Limestone																				
A	0	1.75	0.66	1.0	125	159	12.1	12.3	137	148	60	44	59	51	70	6**	17†	0.9	1795	3780
B	10	3.25	1.08	1.0	133	159	12.2	12.7	137	143	55	51	51	56	73	7**	18	1.3	660	1405
C	25	7.00	1.95	1.0	132	155	12.3	12.3	153	155	56	54	66	66	71	7**	70†	1.7	160	340
	Parts by Wt Fly Ash††																			
A	0.11	1.90	0.73	1.0	126	150	12.0	12.4	133	135	56	50	64	59	73	6**	18†	0.9	1650	3370
A	0.25	2.50	0.80	1.0	126	155	12.0	12.2	137	142	54	55	62	59	76	5**	18†	0.8	1200	2590
A	0.43	3.20	1.08	1.0	130	157	11.8	12.3	140	142	53	51	64	59	75	5**	17	0.8	880	2095
A	0.67	3.80	1.21	1.0	129	156	12.1	12.3	140	142	54	51	62	59	78	6**	18	0.7	795	1990
A	1.00	5.00	1.58	1.0	126	145	12.0	12.3	140	143	61	56	68	65	78	7**	24	0.9	595	1385
	Parts by Wt Loess††																			
A	0.11	1.90	0.74	1.0	131	161	11.8	12.2	140	140	59	52	64	56	77	5	19	0.8	1595	3000
A	0.25	2.50	0.92	1.0	131	162	12.1	12.7	140	143	51	45	61	56	70	7**	18†	1.0	985	1545
A	0.43	2.90	1.05	1.0	141	177	12.2	13.0	140	145	53	47	63	57	71	6-1/2	17†	0.9	735	1350
A	0.67	3.80	1.35	1.0	131	174	11.9	12.7	138	143	51	45	61	55	72	7**	23	1.1	445	845
A	1.00	4.50	1.62	1.0	129	178	11.6	12.4	140	147	55	50	65	60	77	6**	21	1.0	265	535
Traprock																				
	Sand, % Passing No. 100 Sieve																			
A	0	1.75	0.68	1.0	129	146	12.0	12.3	143	143	52	49	64	62	72	5	16†	1.8	2020	4565
B	10	2.00	0.72	1.0	133	158	12.4	12.9	150	157	55	49	60	58	73	6	21†	1.6	1315	3180
C	25	2.25	0.83	1.0	130	168	12.3	12.9	155	157	53	45	64	56	75	6	17†	2.1	1265	2830
	Parts by Wt Fly Ash††																			
A	0.11	1.94	0.73	1.0	128	150	12.2	12.7	152	152	57	53	62	58	73	4**	16†	1.5	1435	3420
A	0.25	2.50	0.90	1.0	130	149	12.3	12.7	158	157	59	54	70	67	75	7**	21†	2.2	1230	2405
A	0.43	2.90	1.03	1.0	136	151	12.3	12.6	152	153	56	54	66	65	74	6**	17†	1.6	1065	2190
A	0.67	3.80	1.24	1.0	142	163	12.3	12.9	155	158	54	52	67	64	73	7**	19	2.2	795	1770
A	1.00	4.50	1.49	1.0	132	157	12.5	12.9	153	153	56	51	69	61	74	7**	22†	1.4	710	1450

* Before or after 15-min interruption in pumping.
** Set after hour shown.
† Set prior to hour shown.
†† Using a sand with a nominal 0 per cent finer than the No. 100 sieve.