ORNL/TM-11867

**OAK RIDGE
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MARTIN MARIETTA

**Evaluation of Dry-Solids-Blend
Material Source for Grouts
Containing 106-AN Waste:
September 1990
Progress Report**

T. M. Gilliam
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C. L. Francis
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**MANAGED BY
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FOR THE UNITED STATES
DEPARTMENT OF ENERGY**

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Chemical Technology Division

EVALUATION OF DRY-SOLIDS-BLEND MATERIAL SOURCE FOR GROUTS
CONTAINING 106-AN WASTE: SEPTEMBER 1990 PROGRESS REPORT

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Date Published—September 1993

Prepared for
Westinghouse Hanford Company
(Activity No. GF 71 01 86 4)

Prepared by the
OAK RIDGE NATIONAL LABORATORY
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MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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PREFACE

This report meets requirements for Milestone 3.5, "Report Recommended Purchase Specifications for Each of Dry Materials," and Milestone 3.6, "Report Results of the Impact on Waste-Form Properties of Dry Materials Source," as described in Statement of Work (SOW) TMG-SOW-90, Revision No. 1, in support of the Westinghouse Hanford Grout Disposal Program. It should be noted that funding reductions, which occurred during the course of this work, reduced the scope of the project. Consequently, the recommendations presented in this report must be considered preliminary, pending additional data scheduled for acquisition in fiscal year 1991.

EXECUTIVE SUMMARY

Stabilization/solidification (S/S) is the most widely used technology for the treatment and ultimate disposal of both radioactive and chemically hazardous wastes. Cement-based products, commonly referred to as grouts, are the predominant materials of choice because of their associated low processing costs, compatibility with a wide variety of disposal scenarios, and ability to meet stringent processing and performance requirements.

Such technology is being utilized in a Grout Treatment Facility (GTF) by the Westinghouse Hanford Company (WHC) for the disposal of various wastes, including 106-AN wastes, located on the Hanford Reservation. The WHC personnel have developed a grout formula for 106-AN disposal that is designed to meet stringent performance requirements. This formula consists of a dry-solids blend containing 40 wt % limestone, 28 wt % granulated blast furnace slag (BFS), 28 wt % ASTM Class F fly ash, and 4 wt % Type I-II-LA Portland cement. The blend is mixed with 106-AN waste at a ratio of 9 lb of dry-solids blend per gallon of waste. This report documents progress made to date on efforts at Oak Ridge National Laboratory (ORNL) in support of WHC's Grout Technology Program to assess the effects of the source of the dry-solids-blend materials on the resulting grout formula.

Numerous sources of dry-solids-blend materials were obtained. Grouts were prepared with various combinations of these materials and synthetic 106-AN waste. The composition of the grout formula was varied in such a manner as to produce a matrix of grouts for each component combination designed to represent the population of variations expected during operation of the GTF. The following characteristics of each grout formulation were determined: critical velocity, frictional pressure drop, 10-min gel strength, fluid density, 28-d unconfined compressive strength, and 28-d drainable water. Based on a comparison of the average characteristics of the reference formulation and the matrix population, it has been determined that there is a statistically significant difference in all measured grout characteristics because of the source of the dry-solids-blend components.

Significantly, all grouts evaluated in this report met GTF performance requirements with regard to critical velocity, frictional pressure drop, 10-min gel strength, and 28-d unconfined compressive strength. Thus, although the source of material affects these grout properties, the impact is not significant relative to the performance that would be desired or expected, based on these properties. However, this conclusion does not apply to 28-d drainable water. Average values for the reference formulation and the matrix routinely exceeded the performance criterion of 5 vol % drainable water. Only the data obtained from Matrixes 1, 6, 7, and 12 met this

criterion with any degree of confidence. Matrixes 1 and 12 contained limestone flour and BFS S-8, while matrixes 6 and 7 contained limestone flour and BFS S-13. Matrixes 1 and 12 also varied the source of cement, while Matrixes 6 and 7 varied the source of fly ash. Thus, it can be inferred that the sources of cement and fly ash do not play a major role in controlling drainable water when used with limestone flour and either BFS S-8 or S-13.

Assuming that the control of drainable water is due, in large part, to the sorption or wetting of the limestone, then, logically, the use of limestone flour with its smaller particle size and, hence, larger surface area, as compared with the ground limestone, should prove beneficial in controlling drainable water. A comparison of average data for 28-d drainable water from Matrixes 4 and 10 supports this premise. The components in Matrixes 4 and 10 are identical except that Matrix 4 used limestone flour, while Matrix 10 used ground limestone. The average value of 28-d drainable water for Matrix 4 was 5.8 vol %, while that for Matrix 10 was 8.2 vol %.

This sensitivity of drainable water with respect to the surface area of limestone within ASTM Class T designation has potentially serious implications on both plant operation and material purchase specifications. Requiring a finer grind of limestone beyond that consistent with ASTM C 602-69 will definitely increase its cost. In addition, without significant additional development effort, neither the acceptable range in particle-size distribution to be used as a purchase specification nor a correlation between particle-size distribution and drainable water can be established. Such a developmental effort is not consistent with budget and schedule constraints. Thus, it can be assumed that, because of differences in particle-size distribution, the plant will experience variations in drainable water from batch to batch of limestone flour. At present, the size of these variations must be considered unknown. It can only be assumed that if the purchase specifications for limestone flour are made consistent with the material used in this study, then the drainable water criterion should be met the majority of the time.

Significantly, the limestone flour controlled the values for 28-d drainable water to within desired limits only in combination with BFS S-8 and S-13. The cause of this synergistic effect is unknown at present. Blaine fineness values for S-8 and S-13, 390 and 567 m²/kg, respectively, essentially bracket the values for the other BFSs tested. Thus, the synergistic effect is apparently not related to the particle size or the grade of the BFS. Some other, as yet to be identified, characteristic of the BFS appears to be the underlying cause. Clearly, efforts to be conducted during the next fiscal year should focus on a detailed characterization of the BFSs and their impact on drainable water.

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ABSTRACT

This report documents progress made to date on the evaluation of dry-solids-blend material source and the subsequent impact on waste-form performance criteria. The evaluation is intended to provide documentation in support of purchase specifications for individual dry-solids-blend components.

1. INTRODUCTION

Stabilization/solidification (S/S) is the most widely used technology for the treatment and ultimate disposal of both radioactive and chemically hazardous wastes. Cement-based products, commonly referred to as grouts, are the predominant materials of choice because of their associated low processing costs, compatibility with a wide variety of disposal scenarios, and ability to meet stringent processing and performance requirements.

Such technology is being utilized in a Grout Treatment Facility (GTF) by the Westinghouse Hanford Company (WHC) for the disposal of various wastes, including 106-AN wastes, located on the Hanford Reservation. The WHC personnel have developed a grout formula for the 106-AN disposal that is designed to meet stringent performance requirements. This formula consists of a dry-solids blend containing 40 wt % limestone, 28 wt % granulated blast furnace slag (BFS), 28 wt % ASTM Class F fly ash, and 4 wt % Type I-II-LA Portland cement. The blend is mixed with 106-AN waste at a ratio of 9 lb of dry-solids blend per gallon of waste. This report documents progress made to date on efforts at Oak Ridge National Laboratory (ORNL) in support of WHC's Grout Technology Program to assess the effects of the source of the dry-solids-blend materials on the resulting grout formula.

2. BACKGROUND

The grout is to be used in Westinghouse Hanford's GTF, where the dry-solids-blend materials are combined with specified volumes of waste in equipment located adjacent to the waste storage tanks. The resulting fresh grout is then pumped to a permanent disposal site

where it hardens and forms an engineered barrier protecting against the intrusion of groundwater and subsequent release of the waste constituents of concern. As such, the grout must meet stringent process and product performance criteria such as:

Product Performance Criteria

Unconfined compressive strength, >60 psi after 28 d
Drainable water, ≤ 5 vol % after 28 d

Process Performance Criteria (based on nominal 2-in. schedule 80 pipe)

Frictional pressure drop, <14 psi/100 ft
Ten-minute gel strength, <100 lb_f/100 ft²
Critical velocity, <60 gpm

It is essential that the dry-solids-blend components be of sufficient quality to meet these requirements when combined to form the grout, and it is economically desirable that these materials be available from as many commercial sources as possible. The four dry-solids-blend components (limestone, fly ash, granulated BFS, and cement) are generic materials produced by numerous commercial vendors, and each can be characterized by well established ASTM standards.

2.1 LIMESTONE

Limestone is added to the grout as an inert material to minimize the heat liberated during the curing process. As such, it adds little to the final strength or durability of the grout product; however, it may contribute to the fluidity of freshly prepared grouts at elevated temperatures. Limestone is an agricultural liming material whose calcium and magnesium compounds are capable of neutralizing soil acidity. As such, it can be characterized by ASTM C 602-69, "Standard Specification for AGRICULTURAL LIMING MATERIALS." As an essentially chemically pure material (CaCO_3), the standard specifies that limestone be classified according to its size distribution. Principal classification specifications are as follows:

<u>Class designation</u>	<u>Passing No. 8 sieve (min. %)</u>	<u>Passing No. 60 sieve (min. %)</u>
S	100	100
T	99	75
O	95	55
N	90	40
E	80	25

In addition, the limestone shall have a "calcium carbonate equivalent" of not less than 80%.

2.2 GRANULATED BLAST-FURNACE SLAG

BFS is added to the grout primarily due to its redox potential and its corresponding ability to reduce Tc(VII) to Tc(IV), which is significantly less mobile. In addition, BFS has cementitious properties and may result in a product with a finer microstructure than that exhibited by simple cement paste. The molten material forms a glassy, granular material on being rapidly chilled, as by immersion in water. It can be used as an additive for construction-grade concrete and can be characterized by ASTM C 989-88, "Standard Specification for GROUND GRANULATED BLAST-FURNACE SLAG FOR USE IN CONCRETE AND MORTARS." As described in ASTM C989-88, the principal characteristics of granulated BFS are as follows:

General properties

Amount retained when wet screened on a 45- μ m (No. 325) sieve, max. %	20
Air content of slag mortar, max. %	12
Sulfide sulfur, max. %	2.5
Sulfate ion reported as SO ₃ , max. %	4.0

Grade-specific properties

	Average of last five consecutive samples	Any individual sample
Slag activity index, min. %		
<u>7-d index</u>		
Grade 80	NR ^a	NR ^a
Grade 100	75	70
Grade 120	90	90
<u>28-d index</u>		
Grade 80	75	70
Grade 100	95	90
Grade 120	115	110

^aNo requirement specified.

In effect, granulated BFS, hereafter referred to as BFS, is also classified according to size distribution or grade. That is, the higher the grade classification, the smaller the particle size.

2.3 FLY ASH

Fly ash is added to the grout for a variety of reasons. It minimizes the CaOH content of the final grout product, reduces the heat liberated during curing (by substitution of BFS and cement), can undergo cementitious reactions when chemically or thermally activated, can increase the fluidity of fresh grouts, and can improve the final strength and microstructure of the product. Fly ash is used routinely as a mineral admixture in concrete for structural applications. As such, it can be characterized by ASTM C 618-85, "Standard Specification for FLY ASH AND RAW OR CALCINED NATURAL POZZOLAN FOR USE AS A MINERAL ADMIXTURE IN PORTLAND CEMENT CONCRETE." Fly ash is classified primarily by gross chemical composition as follows:

Characteristic	Classification		
	N	F	C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min. %	70.0	70.0	50.0
Sulfur trioxide (SO_3), max. %	4.0	5.0	5.0
Moisture content, max. %	3.0	3.0	3.0
Loss on ignition, max. %	10.0	6.0	6.0

ASTM C618-85 specifications indirectly dictate allowable CaO content. In general, CaO is the primary constituent in fly ash beyond those specified in the standard. As such, Class F fly ash would have a significantly lower CaO content than does Class C fly ash; however, since it is not specified directly, the CaO content can vary within any individual fly-ash class.

2.4 CEMENT

Cement is added to the grout as the primary adhesive material that produces a monolithic product. It is a common construction material and can be characterized by

ASTM C 150-84, "Standard Specification for PORTLAND CEMENT." This standard classifies cement primarily by its chemical composition as follows:

	Cement type	
	I-LA	II-LA
Silicon dioxide (SiO_2), min. %		20.0
Aluminum oxide (Al_2O_3), max. %		6.0
Ferric oxide (Fe_2O_3), max. %		6.0
Magnesium oxide (MgO), max. %	6.0	6.0
Sulfur trioxide (SO_3), max. %		
When C3A is 8% or less	3.0	3.0
When C3A is more than 8%	3.5	
Loss on ignition, max. %	3.0	3.0
Insoluble residue, max. %	0.75	0.75
Tricalcium aluminate (C3A), max. %		8.0
Sum of tricalcium silicate and tricalcium aluminate, max. %		58.0
Alkalies ($\text{Na}_2\text{O} + 0.65\text{K}_2\text{O}$), max. %	0.60	0.60

2.5 IMPACT ON MATERIAL SOURCE SELECTION

It is envisioned that a minimum purchase specification for each of the blend components will be consistent with basic applicable ASTM standards for the material (i.e., ASTM C602-69, ASTM C989-88, ASTM C618-85, and ASTM C150-84). As seen in Sects. 2.1 through 2.4, these basic specifications allow some variability in the characteristics of the material, particularly with respect to those materials that are waste materials per se (i.e., fly ash and BFS). Therefore, in selecting materials for evaluation, it was desired that sufficient sources of materials would be identified so as to address variability allowed by the basic ASTM standard. Specifically, this variability should include:

1. variations in particle-size distribution for limestone within a single-class designation,
2. variations in BFS grade from a single source, and
3. variation in CaO content for fly ash meeting Class F specifications.

It should be noted that the basic ASTM cement specifications have historically proven to be adequate. Consequently, a large number of cement sources were not needed.

3. SELECTION OF DRY-SOLIDS-BLEND MATERIAL SOURCE

Known suppliers of the dry-solids-blend materials were contacted, and samples were requested for evaluation in this study. In order to limit the number of materials evaluated to meet budget and schedule commitments, the general operation of the GTF and its location were described to each vendor, and the following constraints were placed on material source:

1. The vendor must be able to supply material for two 1-million-gal disposal campaigns per year.
2. The material must meet applicable ASTM standards as described in Sect. 2.
3. If chosen as a supplier, the vendor must be willing to have its quality assurance program/procedures audited periodically by WHC personnel.
4. Considering the nature or use of the material (waste disposal) and the location of the GTF (Hanford Reservation), the vendor must believe that his material is a viable candidate for eventual use.

It was this last constraint that provided the limiting factor for the materials to be evaluated. As generic bulk materials, the greatest contributor to their ultimate cost is shipping/transportation. Typically, the associated transportation costs limit the source of these materials to a radius of approximately 500 miles from their final destination (Hanford). Since "local" sources of cement, fly ash, and limestone are available, vendors from other parts of the country did not feel that they would be economically competitive; however, as no "local" source of BFS exists, numerous vendors were willing to participate. Significantly, no vendor expressed concern over the fact that the materials would be used for waste disposal.

It is important for the reader to note that these constraints, believed to be realistic with respect to operation of the GTF, allowed the desires detailed in Sect. 2.5 to be met. That is, the materials evaluated encompassed variations allowed by the basic ASTM standards. Specifically, the materials received included:

1. a single-class designation of limestone with different particle-size distributions,
2. a single source of BFS at two different grades, and
3. ASTM Class F fly ash with different CaO contents.

The sources of materials used in this study are documented in the following sections. Additional characterization data are shown in Appendixes A and B.

3.1 CEMENT

Type I-II-LA Portland cement was supplied by two vendors:

Ash Grove Cement West, Inc.
3801 East Marginal Way, South
Seattle, WA 98134
(hereafter referred to as C-88) and

Lafarge Corporation
N. 209 Havana Street
P. O. Box 13189
Spokane, WA 99213-3189
(hereafter referred to as C-91)

3.2 FLY ASH

ASTM Class F fly ash was supplied by:

Pozzolanic International
7525 SE 24th Street
Suite 630
Mercer Island, WA 98040

Fly ash was supplied from two plants:

- (1) Jim Bridger, hereafter referred to as P-56; and
- (2) Centralia, hereafter referred to as P-55.

The CaO content of the Jim Bridger ash was on the order of 6 wt %, while the Centralia fly ash had a CaO content on the order of 12 wt %.

3.3 LIMESTONE

Limestone was supplied by:

Ash Grove Cement West, Inc.
P.O. Box 83007
St. Johns Station
Portland, Oregon 97283-0007

Two different grinds of material were received:

- (1) ground limestone, hereafter referred to as P-58; and
- (2) limestone flour, hereafter referred to as P-59.

Both of these materials would be classified as Class T in accordance with ASTM C 602-69.

3.4 GRANULATED BLAST-FURNACE SLAG

As indicated previously, numerous potential sources of BFS were identified. The suppliers and their internal labels are as follows:

Label	Description	Supplier
S-6	5000 Blaine	The Standard Slag Company 1200 Stambaugh Building P.O. Box 1378 Youngstown, Ohio 44501
S-7	6000 Blaine	The Standard Slag Company 1200 Stambaugh Building P.O. Box 1378 Youngstown, Ohio 44501
S-8		Ash Grove Cement West, Inc. 3801 East Marginal Way, South Seattle, WA 98134
S-9	Grade 120	Blue Circle Atlantic, Inc. P.O. Box 3 Ravena, New York 12143
S-10	Grade 100	Blue Circle Atlantic, Inc. P.O. Box 3 Ravena, New York 12143
S-11	3720 Blaine	C.T. Takahashi & Co., Inc. Bay Vista Building, Suite 230 2815 Second Avenue Seattle, WA 98121
S-12	5060 Blaine	C.T. Takahashi & Co., Inc. Bay Vista Building, Suite 230 2815 Second Avenue Seattle, WA 98121
S-13	3910 Blaine	Standard Slag Cement 360 Jones Road Fruitland, Ontario LOR 1LO
S-14	High Blaine	Standard Slag Cement 360 Jones Road Fruitland, Ontario LOR 1LO

4. METHODOLOGY FOR EVALUATION OF GROUT PROPERTIES

Ultimately, a method of determining the effect of the material source on subsequent properties of the grout prepared using that material was of major interest. In order to address this interest, it was desired to have an experimental matrix that encompassed the expected compositional variations of the material in the grout. Each matrix would be comprised of grouts made from materials from one source (per component). Data obtained from this matrix would be averaged, with the average being representative of the population (or material composition variations) encompassed by the matrix. This matrix would then be repeated using different material sources and the average values compared. Similar averages between matrices would indicate no significant differences in grout properties due to the material source. On the other hand, significant differences between the averages would indicate a dependency on material source. The same result could be achieved by comparing identical observations between matrixes. The data obtained as described in these sections are presented in Appendixes C through I.

4.1 MATRIX SELECTION

The matrix of interest must encompass the compositional variations associated with the dry-solids-blend materials that could be expected to occur during routine operation of the GTF. The range of interest that needs to be encompassed by the matrix is that of composition expected during the normal blending and mixing of limestone (A), fly ash (B), granulated BFS (C), and cement (D), and the mix ratio (E). The basic matrix chosen to evaluate these materials is a quarter of the full factorial for five variables. The basic matrix is shown in Table 1.

Table 1. Basic matrix used for comparison of grouts prepared from various sources of material

Observation No.	Variable ^a				
	A	B	C	D	E
1	-	-	-	+	-
2	-	-	+	-	+
3	-	+	-	-	+
4	-	+	+	+	-
5	+	-	-	+	+
6	+	-	+	-	-
7	+	+	-	-	-
8	+	+	+	+	+
9	R	R	R	R	R

^a - values, 90% of the reference value; + values, 110% of the reference value; R values, reference blend composition.

In this matrix, variables A through D reflect blend composition, while variable E reflects mix ratio. Typically, these variables are thought to possess different units. Blend composition is routinely referred to as wt %, while mix ratio is typically expressed in lb/gal. In reality, the GTF will measure all of these variables based on weight; thus, if the variables are selected based on 1 gal of waste, then all will be in units of pounds.

Based on 1 gal of waste, the reference blend composition (R), in units of pounds, is as follows: limestone flour, 3.6; fly ash, 2.52; granulated BFS, 2.52; cement, 0.36; and mix ratio, 9. During routine operation of the GTF, the weight of individual blend components can be controlled $\pm 5\%$, while the mix ratio can be controlled ± 0.5 lb (on a per-gallon basis). Using this degree of control as a guideline, the "plus" values in the block for variables A, B, C, and D are 110% of the reference value, while "minus" values are 90% of the reference value. For variable E, the plus value is 9.5, while the minus value is 8.5. Note that the variability of the blend components is greater than that expected during routine operation of the GTF.

For the reader's convenience, Table 2 presents the blend compositions (from Table 1) in more typical units. Table 3 presents the blend materials used in each matrix.

4.2 SAMPLE PREPARATION PROCEDURE

Prior to sample preparation for each matrix, the sources of materials were selected. These materials were then used for all blends in a particular matrix. The runs in each matrix were performed in a random order, with the order selected by drawing the numbers 1 through 9 out of a hat. In all data tables presented in this report, the run No. represents the order in which the experiment was performed; the observation No. relates the formulation used to Tables 1 and 2.

4.2.1 Dry-Solids-Blend Preparation

Predetermined weights of each blend component were added to a 3-ft³ Patterson-Kerly twin-shell V-blender in sufficient quantity to accommodate sample requirements for all runs in a matrix. The materials were then tumbled for 23 h. The resulting blended material became the dry-solids blend to be added to the waste in the grout preparation step.

4.2.2 Waste Preparation

Synthetic 106-AN waste of composition shown in Table 4 was prepared in sufficient quantity to accommodate all sample requirements for all runs in a matrix. The waste was maintained at 50°C and continuously stirred for introduction to the grout preparation step.

Table 2. Basic matrix (converted to typical units) used for comparison of grouts prepared from various sources of material

Observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
	Limestone	Fly ash	BFS	Cement	
1	39.63	27.76	27.76	4.84	8.5
2	37.66	26.38	32.19	3.77	9.5
3	37.66	32.19	26.38	3.77	9.5
4	35.31	30.19	30.19	4.32	8.5
5	44.51	25.52	25.52	4.45	9.5
6	42.47	24.35	29.71	3.47	8.5
7	42.47	29.71	24.35	3.47	8.5
8	40.02	27.99	27.99	4.0	9.5
9	40.0	28.0	28.0	4.0	9.0

Table 3. Dry-solids-blend components used in each matrix

Matrix No.	Limestone	Fly ash	Cement	BFS
1	P-59	P-55	C-88	S-8
2	P-59	P-55	C-88	S-10
2R	P-59	P-55	C-88	S-10
3	P-59	P-55	C-88	S-9
4	P-59	P-55	C-88	S-6
5	P-59	P-55	C-88	S-7
6	P-59	P-55	C-88	S-13
7	P-59	P-56	C-88	S-13
8	P-59	P-56	C-88	S-7
9	P-59	P-56	C-88	S-14
10	P-58	P-55	C-88	S-6
11	P-58	P-56	C-88	S-14
12	P-59	P-55	C-91	S-8
13	P-59	P-55	C-91	S-11

Table 4. Composition of synthetic 106-AN waste

Component	Molarity
NaAl(OH)_4	0.421
Na_2SO_4	0.031
NaCl	0.15
NaF	0.0081
$\text{Ca(NO}_3)_2 \cdot 4\text{H}_2\text{O}$	0.002
NaOH (50%)	0.675
NaNO_3	1.29
NaNO_2	0.758
Na_2CO_3	0.382
HEDTA	0.019
Na_4EDTA	0.0044
Glycolic acid (70%) ^a	0.042
$\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$	0.155
$\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}^b$	0.03

^aHydroxyacetic acid.^bSodium citrate.

4.2.3 Grout Preparation

A predetermined volume of the waste was added to a Model N-50 Hobart Mixer, which was set to a low speed (~ 140 rpm), and a predetermined weight of dry-solids material was added over a 10- to 15-s period and blended for a total of 30 s. The mixer was then set to medium speed (~ 285 rpm), and blending was continued for an additional 30 s. The volume of grout prepared was sufficient for:

1. one sample for determination of rheological properties;
2. one sample for determination of drainable water;
3. one sample for determination of grout density; and
4. three samples for determination of compressive strength.

Grout preparation and subsequent data acquisition were repeated three times for each blend in the matrix.

4.3 DETERMINATION OF RHEOLOGICAL PROPERTIES

A total of 350 mL of grout (prepared as described in Sect. 4.2.3) was placed in a FANN viscometer. Shear stress data were obtained as a function of shear-rate at shear rate settings of 600, 300, 200, 100, 181, 90, 60, and 30 rpm. The resulting data are represented by the power-law model as follows:

$$S_s = k'(S_r)^{n'} \quad , \quad (1)$$

where

- S_s = shear stress, lb_f/ft²;
- k' = fluid consistency index, lb_fs^{n'}/ft²;
- S_r = shear rate, s⁻¹; and
- n' = flow behavior index ($0 < n' < 1.0$), dimensionless.

From Eq. (1), the Reynolds number can be calculated by

$$N_{Re} = \frac{1.86V^{2-n'}\rho}{k'(96/d)^{n'}} \quad , \quad (2)$$

where

- N_{Re} = Reynolds number, dimensionless;
- V = fluid velocity, ft/s;
- d_i = inside diameter of pipe, in.; and
- ρ = fluid density, lb/gal.

Critical velocity is determined from Eq. (2) assuming a Reynolds number of 2100 and a schedule 80 pipe of nominal 2-in. diameter. Grout density was determined using an NL Baroid mud balance.

Additional fluid properties are calculated as follows:

$$P_f = \frac{0.039L\rho V^2 f}{d_i} \quad , \quad (3)$$

where

- P_f = frictional pressure drop through a straight pipe, psi;
- L = pipe length, ft; and
- f = fanning friction factor (0.008), dimensionless;

and

$$P_H = \frac{GA_w}{(1.44 \times 10^4)A_p} \quad , \quad (4)$$

where

- P_H = pump head pressure necessary to overcome gel strength, psi;
- G = gel strength, lb/100 ft²;
- A_w = pipe inside surface area, in.²; and
- A_p = inside pipe cross-sectional area, in.².

For calculations presented in the report, the measured gel strength of the fresh grout is the maximum deflection taken from the FANN viscometer at 3 rpm after the grout has remained static for 10 min.

4.4 DETERMINATION OF SOLID-GROUT PROPERTIES

4.4.1 Unconfined Compressive Strength

Freshly prepared grout (Sect. 4.2.3) was poured into three 2-in.-cube molds conforming to ASTM C-109-80 specifications and then placed on a Model VP5101 Syntrol vibrating table at a setting of 6.5 for 20 s. The samples were subsequently stored in a humidity cabinet maintained at 50°C and a relative humidity of >95%. Twenty-eight days after being placed in the molds, the cured grouts were removed and the unconfined compressive strength was determined using a Tinius Olsen Super L Universal Testing Machine in accordance with ASTM C 109-80.

4.4.2 Drainable Water

A total of 250 mL of freshly prepared grout (Sect. 4.2.3) was placed in a polymethylpentene graduated cylinder, which was sealed below the pour spout with an inverted No. 7 stopper. The cylinder was then stored in a cabinet maintained at 50°C. Drainable water was observed at 2 h, 1 d, 7 d, 14 d, 21 d, and 28 d after the grout had been placed in the cylinders.

5. REFERENCE CONDITIONS

In order to evaluate the effects of material source on grout properties with respect to establishing purchase specifications, two questions must be addressed: (1) Is there a statistical difference in grout properties due to material source? and (2) Are these differences significant with respect to the established performance criteria? A discussion of these factors is included in Sects. 6 and 7 of this report; however, prior to a detailed statistical treatment, it is desirable to establish a performance baseline in order to provide guidance on subsequent data interpretation.

In order to provide this guidance, selected grout properties of the reference formulation were compiled from each matrix and then compared with established performance criteria, as shown in Tables 5 through 8. In this context, the reference formulation refers to a dry-solids blend consisting of 40 wt % limestone, 28 wt % ASTM Class F fly ash, 28 wt % BFS, and 4 wt % Type I-II-LA Portland cement, which is subsequently mixed with the waste at a ratio of 9 lb/gal (observation No. 9 in each matrix).

Table 5. Data for critical velocity obtained from on reference formulation^a

Run No.	Critical velocity ^b (gal/min)	95% Confidence interval
MX1-8	14.2 ± 0.8	±2.0
MX2-3	13.9 ± 0.6	±1.5
MX2R-3	14.1 ± 0.5	±1.2
MX3-2	14.1 ± 0.4	±1.0
MX4-1	14.7 ± 0.2	±0.5
MX5-8	16.2 ± 0.2	±0.5
MX6-7	16.1 ± 0.1	±0.2
MX7-3	18.2 ± 0.3	±0.7
MX8-4	16.6 ± 0.5	±1.2
MX9-5	14.8 ± 0.5	±1.2
MX10-1	15.2 ± 0.8	±2.0
MX11-1	15.1 ± 0.4	±1.0
MX12-4	15.7 ± 0.2	±0.5
MX13-9	14.8 ± 0.2	±0.5

Table 6. Data for 10-min gel strength obtained from reference formulation^a

Run No.	10-min gel strength ^b (lb _f /100 ft ²)	95% Confidence interval
MX1-8	6.2 ± 0.4	±1.0
MX2-3	10.8 ± 2.5	±6.2
MX2R-3	3.5 ± 0	±1.2 ^c
MX3-2	13.0 ± 1.0	±2.5
MX4-1	6.3 ± 0.6	±1.5
MX5-8	6.5 ± 0.5	±1.2
MX6-7	4.7 ± 0.3	±0.7
MX7-3	5.5 ± 0.5	±1.2
MX8-4	4.3 ± 0.3	±0.7
MX9-5	4.2 ± 0.3	±0.7
MX10-1	3.5 ± 0.5	±1.2
MX11-1	4.2 ± 0.3	±0.7
MX12-4	5.8 ± 0.3	±0.7
MX13-9	4.7 ± 0.3	±0.7

^aReference formulation corresponds to observation No. 9 in each matrix.

^bAverage value and one standard deviation obtained from three replicates.

^cInterval calculated based on assumed standard deviation of 0.5.

Table 7. Data for 28-d drainable water
obtained from reference formulation^a

Run No.	28-d drainable water ^b (vol %)	95% Confidence interval
MX1-8	2.8 ± 0.8	±2.0
MX2-3	15.3 ± 1.2	±3.0
MX2R-3	8.4 ± 0	±2.0 ^c
MX3-2	8.8 ± 3.3	±8.2
MX4-1	7.9 ± 3.0	±7.5
MX5-8	3.1 ± 0.8	±2.0
MX6-7	4.7 ± 0.8	±2.0
MX7-3	3.5 ± 0.6	±1.5
MX8-4	5.3 ± 0.5	±1.2
MX9-5	6.9 ± 0.5	±1.2
MX10-1	7.7 ± 0.8	±2.0
MX11-1	8.3 ± 0.5	±1.2
MX12-4	4.0 ± 0.4	±1.0
MX13-9	6.7 ± 0.5	±1.2

^aReference formulation corresponds to observation No. 9 in each matrix.

^bAverage value and one standard deviation obtained from three replicates.

^cInterval calculated based on assumed standard deviation of 0.8.

Table 8. Data for 28-d unconfined compressive strength obtained from reference formulation^a

Run No.	28-d unconfined compressive strength ^b (psi)	95% Confidence interval
MX1-8	489 ± 49	±38
MX2-3	346 ± 21	±16
MX2R-3	379 ± 30	±23
MX3-2	306 ± 33	±25
MX4-1	492 ± 69	±53
MX5-8	380 ± 23	±18
MX6-7	481 ± 30	±23
MX7-3	383 ± 30	±23
MX8-4	392 ± 48	±37
MX9-5	367 ± 32	±25
MX10-1	377 ± 55	±42
MX11-1	510 ± 75	±58
MX12-4	491 ± 35	±27
MX13-9	436 ± 41	±32

In Tables 5 through 7, average values for the selected properties were obtained from three replicate measurements on the reference formulation from each matrix, while average values reported in Table 8 were obtained from nine replicate measurements. The 95% confidence interval was calculated as follows:

$$C = \pm t_{\alpha/2}(\sigma/\sqrt{n}) , \quad (5)$$

where

C = $(1 - \alpha)\%$ confidence interval,

$t_{\alpha/2}$ = value from t tables,

σ = standard deviation, and

n = number of replicate data.

The confidence interval would be applied to the average value (u) as follows: $u \pm C$. That is, for a value for the selected property of u , the data show an interval extending from $(u - C)$ to $(u + C)$ that includes the true value of u with 95% probability. One would then be confident that the reference formulation meets the desired performance criteria with a high degree of confidence if the value of u meets the performance criterion and the calculated confidence interval does not include the value for the performance criterion. It must be noted that the above discussion is limited to the reference formulation and is intended only to provide guidance to subsequent data interpretation; it is not intended to address the effects of variations in either the dry-solids-blend composition or the mix ratio.

As shown in Tables 5, 6, and 8, the confidence intervals for critical velocity, 10-min gel strength, and 28-d unconfined compressive strength do not include the performance criteria values of 60 gpm, 100 lb_f/100 ft², and 60 psi, respectively. This provides preliminary indications that vendor source will not affect these characteristics to the point where the grout will not be able to meet performance criteria with respect to these characteristics.

As shown in Table 7, the confidence interval for 28-d drainable water includes or exceeds the performance criterion value of <5% for all of the data except MX1-8, which has a confidence interval of 0.8 to 4.8; however, the data from Matrixes 1, 2, and 3 are an anomaly, which will be discussed in Sect. 7. These data indicate that the ability of the reference formulation to meet the drainable water criterion of ≤ 5 vol % is highly suspect; but, as the average values range from 8.4 to 3.1 vol %, there is some indication that vendor source may affect the drainable water. Clearly, drainable water becomes a key variable to be addressed in the subsequent data analysis.

6. STATISTICAL ANALYSIS TO DETERMINE EFFECTS OF MATERIAL SOURCE

Section 5 indicated that material source may have a significant effect on grout properties. In addition, 28-d drainable water was identified as a key variable that could be used to evaluate this potential effect. To determine whether the source of the components of the grout makes a difference in the grout's physical properties, one must compare the effects of a number of different "treatments" (i.e., different combinations of grout material sources) on grout properties.

6.1 APPROACH UTILIZED IN STATISTICAL ANALYSIS

Eleven different material source mixtures (or matrixes), denoted MX2R and MX4 through MX13, were compared to determine differences. The following physical properties were examined: compressive strength (CS); critical velocity (CV); frictional pressure drop (PD); pump-head pressure (PH); 10-min. gel strength (GS); density (DN); and drainable water after 2 h (D2), 1 d (D1), 7 d (D7), 14 d (D14), 21 d (D21), and 28 d (D28).

To perform this analysis, data from observation Nos. 9-A, -B, and -C from each matrix were utilized. In this context, observation No. 9 is a "treatment." It should be noted that observation No. 9 corresponds to the reference formulation as discussed in Sect. 5. The statistical technique used is called "analysis of variance," or ANOVAR (see Ref. 1, Chap. 6). In this approach, the statistical variance in the values of a physical property (e. g., D28) is calculated by two different procedures. One of these uses the differences within replicate runs of a treatment to estimate the variance, while the other uses differences between treatments (from the 11 matrixes) to estimate the same statistical parameter. An "F-test" is then performed on the ratio of these two estimates of the variance to determine whether viable differences exist. If the F-test indicates that the variance calculated by the "between-treatments" method is significantly larger than the "within-treatment" number, then it may be said that the different material sources do cause changes in the physical properties.

The F-test alone would not indicate the significance of differences between two specific sources but, rather, that differences exist between the 11 combinations that were tried. In order to address significant differences between specific sources, Tukey's paired comparison procedure (see Ref. 1., p. 204) may be used. This approach uses the studentized range parameter (or "Q-test") in order to set a lower limit by which values from two treatments or sources of material must vary in order to be meaningful.

6.2 COMPARISON OF REFERENCE FORMULATION TREATMENTS

Table 9 contains a list of the F-test and Q-test results for the 11 treatments. Additional data are shown in Appendixes J and K. The tabular entries indicate that significant differences were detected between the treatments or material sources in all physical property measurements. The 99% confidence level for the F-test is less than 4; thus, values greater than 4 indicate that differences exist. As shown in Table 9, it is quite evident that there are differences in all physical properties due to material source. For example, the F-test ratio for 28-d drainable water (D28) is 20.75, which is well beyond the critical value of 4.

For the properties that show viable differences, one can use the Q-test value to compare sources of materials in pairwise fashion. In the case of compressive strength (CS), the tabulated Q-test value is 118 psi (see Appendix J). This means that the absolute value of the difference in CS between any two sources in question (i.e., treatments) must be greater than 118 psi in order to verify that a significant difference exists. For this test, one should use the values obtained by averaging the A, B, and C runs for each treatment. With this technique, one may examine the differences between any pair of material sources or treatments.

Although a statistical comparison has been performed on each of the physical characteristics, it is important to note that many of these comparisons do not yield additional information (i.e., many of the characteristics depend on one another). For example, within experimental error, a comparison of the 2-h drainable water (D2) values yields the same statistical information as the 28-d drainable water data. The same can be said for:

1. frictional pressure drop, which is dependent on critical velocity; and
2. pump-head pressure, which is dependent on 10-min gel strength.

However, a comparison of all determined physical characteristics is presented in this report to show that a comparison of these dependent characteristics will provide the same statistical information as a comparison of the nonrelated characteristics. Such documentation will provide the basis for reductions in the required measurements for future experiments on this issue.

An interesting point is emphasized when examining the frictional pressure drop data (PD) (see Appendix J). The precision of these data is insufficient to determine whether statistically significant differences exist. The data take on one of two values only, 5.5 or 5.6, and in only one case (MX13) is there a difference in the three replicates. This yields an extremely low and, probably, misleading estimate for the variance. Therefore, these data for frictional pressure drop should not be used to assess differences based on source.

Table 9. F-test and Q-test values in reference formulation from 11 matrixes

Characteristic	F-test ratio	Q-test lower limit	Significant difference?
CS	6.0	118.4 psi	Yes
CV	29.1	1.4 gal/min	Yes
PD	24.4	0.05 psi/100 ft ²	Yes
PH	23.1	0.43 psi	Yes
GS	27.4	1.7 lb _f /100 ft ²	Yes
DN	26.9	0.11 lb/ft ³	Yes
D2	21.3	6.3 mL	Yes
D1	20.3	7.7 mL	Yes
D7	23.8	7.7 mL	Yes
D14	24.5	7.8 mL	Yes
D21	24.0	7.8 mL	Yes
D28	20.8	8.5 mL	Yes

6.3 APPLICATION TO FIELD OPERATION

As discussed in Sect. 6.2, there is a statistically significant difference in grout characteristics based on material source. This conclusion was derived from comparisons of a single treatment from each source. It is recognized that, during routine operation of the GTF, variations in the reference formulation will occur. As discussed in Sect. 4, the formulations utilized in each matrix represent a quarter factorial of the variations that can be expected. As such, the "population" of formulations contained in each matrix is believed to be representative of the actual population of formulations expected during operation of the GTF. Thus, analysis of the overall response of each matrix should be representative of the expected range of possible operating conditions in the GTF. The analysis-of-variance approach discussed in Sects. 6.1 and 6.2 can be used to compare physical properties obtained over the operating range as a whole. That is to say, all of the data points for a particular grout characteristic from the various runs within a matrix can be combined (i.e., averaged) to obtain a characteristic value for the matrix of interest. These characteristic values, or averages, can then be analyzed as discussed in Sects. 6.1 and 6.2.

F-test and Q-test values obtained for these matrix average characteristics are listed in Table 10. Additional data are presented in Appendix K. As seen in Table 10, there is a significant statistical difference between the grout sources, in each case, as indicated by the large values of the ratio of variances. This information serves to document that no anomalies are introduced by variations in the formulation composition, and that, in the future, the necessary statistical comparison can be performed on a more limited number of experiments, such as those described in Sects. 6.1 and 6.2.

7. APPLICATION TO PERFORMANCE CRITERIA

As discussed in Sects. 5 and 6, grout characteristics show a statistically significant difference based on material source. This is not surprising because the various sources of materials translate to materials of differing particle size and chemical composition. Since the fluid grout can be characterized as a slurry, its properties should be dependent on the physical characteristics (e. g., particle size) of its individual components. Characteristics of the final product are determined after the cementitious reactions have occurred. Because the rate and, possibly, final product of these chemical reactions should be dependent on the particle size and chemical composition of the grout components, the product's characteristics may also be

Table 10. F-test and Q-test values for matrix
average characteristics

Characteristic ^a	F-test ratio	Q-test lower limit	Significant difference?
CS	14.2	82.8 psi	Yes
CV	18.1	1.0 gal/min	Yes
PD	7.8	0.13 psi/100 ft ²	Yes
PH	10.4	0.5 psi	Yes
GS	10.7	1.35 lb/100 ft ²	Yes
DN	7.8	0.13 lb/ft ³	Yes
D2	31.0	3.9 mL	Yes
D1	26.9	4.7 mL	Yes
D7	24.0	4.8 mL	Yes
D14	23.8	4.9 mL	Yes
D21	22.4	4.9 mL	Yes
D28	21.9	5.0 mL	Yes

^aSee Sect. 6.1 for definitions.

dependent on the components. The key question then becomes, "Are the differences in grout characteristics due to material source significant with respect to performance requirements?" That is, "Do the grout characteristics vary sufficiently to exceed performance constraints?"

7.1 COMPARISON OF MATRIX CHARACTERISTIC VALUES

As discussed previously, each matrix is comprised of nine runs that correspond to nine variations in the reference formulation. These variations are designed to be representative of the total population of variations expected during operation of the GTF. As such, the average of any particular grout characteristic from all runs within a matrix can reasonably be expected to approximate the average value of that characteristic obtained during operation of the GTF, using the source of materials in the matrix.

Characteristic values (u) averaged over all applicable data within a matrix are shown in Tables 11, 12, 13, and 14 for critical velocity, 10-min gel strength, 28-d drainable water, and 28-d unconfined compressive strength, respectively. Also shown in the tables are the calculated confidence intervals ($\pm C$). The confidence interval (C) combined with the average value (u) can be used as follows: The data show that the interval extending from ($u - C$) to ($u + C$) includes the true value of u with 95% probability. Clearly, the values obtained for critical velocity, 10-min gel strength, and 28-d unconfined compressive strength are well within the performance criteria for all of the matrixes. Thus, for the materials evaluated in this study, material source has a negligible impact on these characteristics relative to the performance criteria.

Consistent with analysis presented in Sect. 5, 28-d drainable water continues to be a key variable for matrix average values. For both the averages obtained from the reference formulation (Sect. 5) and those for the entire matrix (presented here), the average values for 28-d drainable water were below the performance criterion of 5 vol % only for data from Matrixes 1, 5, 6, 7, and 12. Applying the 95% confidence interval to the matrix-average values results in the following:

<u>Matrix</u>	<u>95% Confidence Interval for average 28-d drainable water (vol %)</u>
1	3.0 to 4.2
5	3.8 to 5.6
6	2.3 to 3.9
7	2.0 to 3.6
12	4.0 to 5.0

Table 11. Characteristic values for critical velocity obtained by averaging applicable matrix data

Matrix No.	Critical velocity ^a (gal/min)	95% Confidence interval
MX1	14.6 ± 1.5	±0.6
MX2	13.6 ± 1.2	±0.5
MX2R	13.6 ± 1.2	±0.5
MX3	15.0 ± 1.0	±0.4
MX4	15.0 ± 1.2	±0.5
MX5	16.0 ± 1.1	±0.4
MX6	16.3 ± 1.5	±0.6
MX7	17.1 ± 1.3	±0.5
MX8	16.4 ± 0.9	±0.4
MX9	15.7 ± 1.1	±0.4
MX10	15.4 ± 1.0	±0.4
MX11	15.0 ± 0.8	±0.3
MX12	15.7 ± 1.1	±0.4
MX13	14.9 ± 1.0	±0.4

^aAverage value and one standard deviation obtained from 27 data points.

Table 12. Characteristic values for 10-min gel strength obtained by averaging all applicable matrix data

Matrix No.	10-min gel strength ^a (lb/100 ft ²)	95% Confidence interval
MX1	6.4 ± 1.2	±0.5
MX2	8.9 ± 3.9	±1.5
MX2R	3.9 ± 0.7	±0.3
MX3	15.4 ± 4.6	±1.8
MX4	5.5 ± 1.1	±0.4
MX5	5.5 ± 1.0	±0.4
MX6	5.6 ± 1.3	±0.5
MX7	5.9 ± 1.0	±0.4
MX8	5.9 ± 3.9	±1.5
MX9	4.6 ± 0.9	±0.4
MX10	3.9 ± 0.5	±0.2
MX11	4.1 ± 1.0	±0.4
MX12	7.0 ± 1.7	±0.7
MX13	5.0 ± 1.0	±0.4

^aAverage value and one standard deviation obtained from 27 data points.

Table 13. Characteristic values for 28-d drainable water obtained by averaging all applicable matrix data

Matrix No.	28-d drainable water ^a (vol %)	95% Confidence Interval
MX1	3.6 ± 1.6	±0.6
MX2	13.2 ± 4.1	±1.6
MX2R	9.1 ± 3.0	±1.2
MX3	9.5 ± 3.6	±1.4
MX4	5.8 ± 3.1	±1.2
MX5	4.7 ± 2.4	±0.9
MX6	3.1 ± 1.9	±0.8
MX7	2.8 ± 1.9	±0.8
MX8	5.1 ± 2.1	±0.8
MX9	7.0 ± 1.9	±0.8
MX10	8.2 ± 2.2	±0.9
MX11	8.1 ± 1.6	±0.6
MX12	4.5 ± 1.2	±0.5
MX13	8.0 ± 2.0	±0.8

^aAverage value and one standard deviation obtained from 27 data points.

Table 14. Characteristic values for 28-d unconfined compressive strength obtained by averaging all applicable matrix data

Matrix No.	28-d unconfined compressive strength (psi)	95% Confidence interval
MX1	431 ± 61	±14
MX2	371 ± 37	±8
MX2R	349 ± 45	±10
MX3	372 ± 56	±12
MX4	433 ± 84	±19
MX5	425 ± 80	±18
MX6	473 ± 89	±20
MX7	377 ± 80	±18
MX8	386 ± 86	±19
MX9	388 ± 59	±13
MX10	431 ± 106	±24
MX11	579 ± 183	±41
MX12	527 ± 73	±16
MX13	429 ± 71	±16

The confidence interval for Matrix 5 exceeds the performance criterion of 5%. Thus, it can be stated with a high degree of confidence (95%) that, on the average, formulation variations expected in the GTF with those materials used in Matrixes 1, 6, 7, and 12 will meet performance criteria with respect to critical velocity, 10-min gel strength, 28-d unconfined compressive strength, and 28-d drainable water.

7.2 MATRIXES 1, 2, AND 3

As mentioned previously, data obtained from Matrixes 1, 2, and 3 represent an anomaly with respect to the other matrixes. Grouts in Matrixes 1, 2, and 3 were prepared with synthetic 106-AN waste prepared from off-the-shelf chemicals. Beginning with Matrix 4, all grouts were prepared with a new batch of waste comprised of a fresh shipment of chemicals. The waste used in Matrixes 1, 2, and 3 contained a precipitate, while the new batch did not. Analysis of the precipitate indicated it to be predominantly $\text{Al}(\text{OH})_3$, in the form of Gibbsite and Bayerite. Thus, the data from Matrixes 1, 2, and 3 are not consistent with the other matrixes. In order to assess the effects of the precipitate on grout characteristics, Matrix 2 was repeated with a new batch of waste. The repeat matrix was labeled MX2R. A comparison between matrix average values obtained for Matrixes 2 and 2R is as follows:

Characteristic	Matrix average at the 95% confidence level	
	MX2	MX2R
Critical velocity, gpm	13.6 ± 0.5	13.6 ± 0.5
10-min gel strength, $\text{lb}_f/100 \text{ ft}^2$	8.9 ± 1.5	3.9 ± 0.3
28-d unconfined compressive strength, psi	371 ± 8	349 ± 10
28-d drainable water, vol %	13.2 ± 1.6	9.1 ± 1.2

This comparison indicates that the precipitate behaves as an inert solid material. That is, the grouts prepared with the precipitate present are characterized by little change in critical velocity but an increase in gel strength, drainable water, and unconfined compressive strength. Since the quantity of contained precipitate was not determined, it is not possible to determine the change in characteristics as a function of contained precipitate. As discussed previously, critical velocity, gel strength, and unconfined compressive strength met performance criteria. Consequently, if we assume that the grouts prepared with these materials, using waste containing no precipitate, will result in a reduction in average values for these characteristics, then the new

grouts should be consistent with the performance requirements. However, assuming that the 31% reduction in drainable water is maintained for Matrixes 1 and 3, only Matrix 1 will meet the performance criterion with respect to drainable water.

8. IMPACT ON PURCHASE SPECIFICATIONS

The dry-solids-blend components used in this project included (1) ASTM Class T limestone at two particle-size distributions, (2) ASTM Class F fly ash at two CaO contents, (3) Type I-II-LA Portland cement from two distinct sources, and (4) BFS from numerous sources with Blaine fineness ranging from 390 to 627 m²/kg. Although grade classification of the BFS is to be performed next fiscal year, the Blaine fineness values are believed to correspond to grades of 100 and 120. These materials encompassed expected variations permitted under the basic applicable ASTM standards.

8.1 RHEOLOGICAL PROPERTIES

The following rheological properties were determined in this study: critical velocity, frictional pressure drop, 10-min gel strength, pump-head pressure, and density. Average values determined on both the reference formulation and a matrix designed to represent the population of formulation variations expected in the GTF indicated that, with a high degree of confidence, all combinations of material sources tested easily met performance requirements with respect to these characteristics. Thus, with regard to these characteristics, the basic ASTM standards appear to be sufficient in order to properly characterize, or give specifications for, the dry-solids-blend materials. That is, in order to meet the desired rheological property performance criteria, the following purchase specifications appear to be sufficient:

1. Limestone: ASTM C 602-69 Class T - It is believed that other class designations would also meet the rheological criteria; however, since only Class T has been evaluated, purchase specifications should remain consistent with the existing support documentation.
2. Fly ash: ASTM C 618-85 Class F - The data presented in this report evaluated Class F fly ash at CaO contents of 6 and 12%. This provides reasonable assurance that a variable CaO content (allowed by C618-85 specifications) has no deleterious impact on rheological properties. In theory, the CaO content of Class F fly ash could range as high as 30%; however, in practice, the value is more typically less than 15%. Since vendors have no direct

means of controlling CaO content, it is not desirable to make it a purchase specification; however, it is recommended that reporting of the CaO content be a requirement. It is expected that the majority of potential vendors will have fly ash with CaO contents below 15%; any values significantly above 15% should be viewed as cause for concern.

3. Cement: ASTM C150-84 Type I-II-LA Portland cement - As discussed previously, cement, as classified by C 150-84, has a long historical "track record"; thus, these standard specifications are sufficient.
4. BFS: ASTM C 989-88 Grade 100 and 120 - The grade specifications must be considered preliminary at this point. BFSs evaluated included Blaine fineness values of 390 to 627 m²/kg, which are believed to be consistent with grades 100 and 120 specifications; however, characterization, with respect to grade, is scheduled for fiscal year 1991.

8.2 PRODUCT PROPERTIES

Two product properties, 28-d unconfined compressive strength and drainable water, were determined for each study. The average values determined on both the reference formulation and a matrix designed to represent the population of formulation variations expected in the GTF indicated that, with a high degree of confidence, all combinations of material source tested easily met performance requirements with respect to 28-d unconfined compressive strength. Thus, with regard to this characteristic, the basic ASTM standards (Sect. 8.1) appear to be sufficient in order to properly characterize, or give specification for, the dry-solids-blend materials. However, the same conclusion did not hold true for 28-d drainable water. Average values for the reference formulation and the matrix routinely exceeded the performance criterion of 5 vol % drainable water. Only data obtained from Matrixes 1, 6, 7, and 12 met this criterion with any degree of confidence. Matrixes 1 and 12 contained limestone flour and BFS S-8. Matrixes 6 and 7 contained limestone flour and BFS S-13. Matrixes 1 and 12 also varied the source of cement, while Matrixes 6 and 7 varied the source of fly ash; thus, it can be inferred that the sources of cement and fly ash do not play a major role in controlling drainable water when used with limestone flour and either BFS S-8 or S-13.

Assuming that the control of drainable water is due, in large part, to the sorption or wetting of the limestone, then the use of limestone flour, with its smaller particle size, and, hence, larger surface area as compared with the ground limestone, would prove beneficial in controlling the drainable water. A comparison of average 28-d drainable water data from

Matrixes 4 and 10 supports this premise. Components in Matrixes 4 and 10 are identical except that Matrix 4 used limestone flour, while Matrix 10 used ground limestone. The average 28-d drainable water for Matrix 4 was 5.8 vol %, while that for Matrix 10 was 8.2 vol %.

This sensitivity of drainable water, with respect to the surface area of limestone within the ASTM Class T designation, has potentially serious implication on both plant operation and material purchase specifications. Requiring a finer grind of limestone beyond that consistent with ASTM C 602-69 will certainly increase its cost. In addition, without significant additional development effort, neither the acceptable range in particle-size distribution to be used as a purchase specification nor a correlation between particle-size distribution and drainable water can be established. Such a developmental effort is not consistent with budget and schedule constraints. Thus, it can be assumed that, because of differences in particle-size distribution, the plant will experience variations in drainable water from batch to batch of limestone flour. At present, the size of these variations must be considered unknown. It can only be assumed that if the purchase specifications for limestone flour are made consistent with the material used in this study, the drainable water criterion should be met most of the time.

Significantly, the limestone flour controlled the 28-d drainable water content to within desired limits only in combination with BFS S-8 and S-13. The cause of this synergistic effect is unknown at present. The Blaine fineness values for S-8 and S-13, 390 and 567 m²/kg, respectively, essentially bracket the values for the other BFSs tested. Thus, the synergistic effect does not appear to be due to the particle size or grade of the BFS. Some other, as yet to be identified, characteristic of the BFS is apparently the cause. Another possibility is that a unique product microstructure created a situation whereby only those samples that contained the limestone flour, in combination with BFS S-8 and S-13, exhibited satisfactory 28-d drainable water values. This possibility might have been verified by the use of comparative micrographic evidence. As such, it is recommended that the acquisition of such micrographic information become a routine part of studies such as this.

Based on available data, only limestone flour in combination with BFSs S-8 and S-13 achieved the desired drainable water criterion. Specifying the purchase of these materials from the designated sources may impact both their cost and their long-term availability. In addition, lack of an understanding of the specific desirable characteristic, and, hence, the ability to control it through the use of purchase specifications, means that the variability of the material from these sources may well impact drainable water.

It must be recognized that drainable water data were obtained at 50°C in this study, while grouts to be produced within the GTF are expected to experience higher temperatures. The data presented in this report were obtained at 50°C to allow measurements to be taken at

various time intervals. At temperatures above 50°C, losses due to evaporation become significant, requiring specialty containers to seal the samples. These containers do not allow visual observation of drainable water without opening the containers and, hence, rendering the sample unusable for further observation. The schedule and the cost constraints for this project were not compatible with the large number of such containers needed. Nonetheless, the data are thought to be sufficient to identify the acceptability of the grout product with respect to the drainable water criterion. On the other hand, it should be pointed out that a companion study being performed at Pacific Northwest Laboratories (PNL) indicates that drainable water may decrease with increasing cure temperatures. Although unlikely that the decrease would be sufficient to meet this criterion, it is recommended that the data base associated with the PNL study be assessed to determine whether the current documentation is sufficient to allow the extrapolation of data presented here to expected cure temperatures.

Of the grout characteristics studied in this report, drainable water has been identified as the key variable relative to purchase specifications. Relaxation of this criterion would greatly increase the available sources of materials and, hence, allow a more competitive bid. In light of this situation, it is recommended that consideration be given to (1) formulation enhancement to improve its retention of water and/or (2) relaxation of the drainable water criterion.

9. SUMMARY AND RECOMMENDATIONS

This report documents progress made to date on efforts in support of the WHC Grout Technology Program to assess the effects of the source of the dry-solids-blend materials on grout characteristics of the 106-AN formulation. This formulation consists of a dry-solids blend containing 40 wt % limestone, 28 wt % granulated blast furnace slag, 28 wt % ASTM Class F fly ash, and 4 wt % Type I-II-LA Portland cement. The blend is mixed with 106-AN waste at a ratio of 9 lb of dry-solids blend per gallon of waste.

Numerous sources of dry-solids-blend materials were obtained. Grouts were prepared with various combinations of these materials and synthetic 106-AN waste. The composition of the grout formula was varied in such a manner as to produce a matrix of grouts for each component combination designed to represent the population of variations expected during operation of the GTF. The following characteristics were determined for each grout formulation: critical velocity, frictional pressure drop, 10-min gel strength, fluid density, 28-d unconfined compressive strength, and 28-d drainable water. Based on a comparison of the average characteristics of the reference formulation and the matrix population, it has been

determined that there is a statistically significant difference in all measured grout characteristics because of the source of the dry-solids-blend components.

Significantly, all grouts evaluated in this report met GTF performance requirements with respect to critical velocity, frictional pressure drop, 10-min gel strength, and 28-d unconfined compressive strength. Thus, although the source of material affects the grout properties, the impact is not significant relative to the performance that is desired or expected, based on these properties. However, the same conclusion cannot be drawn with respect to 28-d drainable water. Average values for the reference formulation and the matrix routinely exceeded the performance criterion of 5 vol % drainable water. Only data obtained from Matrixes 1, 6, 7, and 12 met this criterion with any degree of confidence. Matrixes 1 and 12 contained limestone flour and BFS S-8, while Matrixes 6 and 7 contained limestone flour and BFS S-13. Matrixes 1 and 12 also varied the source of cement, while Matrixes 6 and 7 varied the source of fly ash. Thus, it can be inferred that the sources of cement and fly ash do not play a major role in controlling drainable water when used with limestone flour and either BFS S-8 or S-13.

Assuming that control of the drainable water is due, in large part, to the sorption or wetting of the limestone, then, the use of limestone flour with its smaller particle size and, hence, larger surface area, as compared with the ground limestone, should prove beneficial in controlling drainable water. A comparison of average 28-d drainable water data from Matrixes 4 and 10 supports this premise. Components in Matrixes 4 and 10 are identical except that Matrix 4 used limestone flour, while Matrix 10 used ground limestone. The average 28-d drainable water for Matrix 4 was 5.8 vol %, while that for Matrix 10 was 8.2 vol %.

This sensitivity of drainable water with respect to the surface area of limestone within the ASTM Class T designation has potentially serious implications on both plant operation and material purchase specifications. Requiring a finer grind of limestone beyond that consistent with ASTM C 602-69 will certainly increase its cost. In addition, without significant additional developmental effort, neither the acceptable range in particle-size distribution to be used as a purchase specification nor a correlation between particle-size distribution and drainable water can be established. Such an effort is not consistent with budget and schedule constraints; thus, it can be assumed that, because of differences in particle-size distribution, the plant will experience variations in drainable water from batch to batch of limestone flour. At present, the size of these variations must be considered unknown. It can only be assumed that if the purchase specifications for limestone flour are made consistent with the material used in this study, then drainable water criterion should be met the majority of the time.

Significantly, the limestone flour controlled 28-d drainable water to within the desired limits only in combination with BFS S-8 and S-13. The cause of this synergistic effect is

unknown at present. The Blaine fineness values for S-8 and S-13, 390 and 567 m²/kg, respectively, essentially bracket the values for the other BFSs tested. Thus, the synergistic effect does not appear to be due to the particle size or grade of the BFS. Some other, as yet to be identified, characteristic of the BFS appears to be the cause. Clearly, efforts to be conducted next fiscal year should focus on a detailed characterization of the BFSs and their impact on drainable water.

The statistical treatment of the data in this report clearly indicates that the comparison of reference formulation characteristics provides information similar to that obtained by comparing the average matrix values. Thus, during the studies to be conducted next fiscal year, the number of experiments may be greatly reduced as compared with those summarized in this report. (This reduction is required in order to meet existing budget and schedule constraints.) It should also be noted that the data base contained in this report, combined with material characterization data (to be obtained next fiscal year), should provide guidance as to additional experiment requirements and insight to additional purchase specifications.

10. ACKNOWLEDGMENT

The authors wish to thank T. L. Welsh and C. M. Sager, Westinghouse Hanford Company, for their assistance in developing the blend-composition matrix. They also wish to thank the following individuals for their technical review of this report: M. T. Harris and J. L. Shoemaker, Martin Marietta Energy Systems, Inc.; and E. F. Riebling, Westinghouse Hanford Company.

11. REFERENCES

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APPENDIXES

Appendix A: Characterization of Dry-Solids-Blend Materials

Source: Ash Grove Cement West, Inc.
P. O. Box 83007
St. Johns Station
Portland, Oregon 97283-0007

Label: P-58 (Ground) and P-59 (Flour)

Mesh	Ground limestone ^a (%)	Limestone flour ^b (%)
10	99	100
20	97	99
40	90	98
60	80	94
100	70	90

^aLabel P-58.

^bLabel P-59.

Cement, Type I-II-LA

Source: Ash Grove Cement West, Inc.
3801 East Marginal Way, South
Seattle, Washington 98134

Label: C-88

Origination: Durkee, Oregon

CHEMICAL COMPOSITION, %

SiO ₂	22.38
Al ₂ O ₃	3.79
Fe ₂ O ₃	4.25
CaO	64.43
MgO	1.61
SO ₃	2.04
Loss on ignition	1.24
Insoluble residue	0.23
Total alkalies (as Na ₂ O)	0.43
C ₃ S	54.8
C ₂ S	22.8
C ₃ A	2.9
C ₄ AF	12.9

PHYSICAL TESTS

Blaine fineness	360 m ² /kg
Normal consistency	24.6%
Setting time - Vicat	
Initial	150 min
Final	235 min
False set	86.8%
Autoclave expansion	+0.039%
Air entrainment	7.0%
Compressive strength, psi	
1 d	1345
3 d	2860
7 d	3985

Cement, Type II

Source: Lafarge Corporation
N. 209 Havana Street
Spokane, Washington 99213-3189

Label: C-91

Origination: Exshaw, Alberta, Canada

CHEMICAL COMPOSITION, %

SiO ₂	21.14
Al ₂ O ₃	3.59
Fe ₂ O ₃	5.18
CaO	61.55
MgO	4.32
SO ₃	2.42
Loss on ignition	0.94
Insoluble residue	0.20
Total alkalis (as Na ₂ O)	0.58
C ₃ S	51.13
C ₂ S	22.03
C ₃ A	0.89
C ₄ AF	15.77

PHYSICAL TESTS, psi

Blaine fineness	386 m ² /kg
Setting time - Vicat	
Initial	115 min
Final	195 min
Autoclave expansion	0.10%
Air entrainment	7.4%
Compressive strength, psi	
3 d	3065
7 d	3875

Fly Ash, ASTM Class F

Source: Pozzolan Northwest
7525 SE 24th Street
Suite 630
Mercer Island, Washington 98040

Label: P-55

Origination: Centralia Plant, Washington

CHEMICAL COMPOSITION, %

Silicon dioxide	45.93	
Aluminum oxide	23.32	
Iron oxide	6.46	
Total		75.71
Sulfur trioxide		0.59
Calcium oxide		11.67
Moisture content		0.05
Loss on ignition		0.06

Fly Ash, ASTM Class F

Source: Pozzolanic International
7525 SE 24th Street
Suite 630
Mercer Island, Washington 98040

Label: P-56

Origination: Jim Bridger Plant

CHEMICAL COMPOSITION, %

Silicon dioxide	62.73	
Aluminum oxide	18.16	
Iron oxide	5.08	
Total		85.97
Sulfur trioxide		0.44
Calcium oxide		6.08
Moisture content		0.03
Loss on ignition		0.26

Granulated Blast Furnace Slag

Source: The Standard Slag Company
 1200 Stambaugh Building
 P. O. Box 1378
 Youngstown, Ohio 44501

Label: S-6 (5000 Blaine) and S-7 (6000 Blaine)

General Properties

<u>CHEMICAL PROPERTIES</u>	<u>RANGE, %</u>
CaO	36 - 41
MgO	10 - 13
SiO ₂	34 - 36
Al ₂ O ₃	8 - 11
FeO	0.4 - 0.8
MnO	0.4 - 0.8
S	1.5 - 2.0
Na ₂ O equivalent	<1.0
Base/acid ratio	1.0 - 1.2

<u>PHYSICAL PROPERTIES</u>	
Color	Off-white
Specific gravity	2.90 - 2.95
Blaine fineness, cm ² /g	4000 - 5500
325 mesh, % retained	2 - 5

Granulated Blast Furnace Slag

Source: Ash Grove Cement West, Inc.
3801 East Marginal Way, South
Seattle, Washington 98134

Label: S-8

Origination: Kawasaki Steel, Japan; ground in Seattle Plant

CHEMICAL

Sulfur (as sulfide)	Max. 2.5%	0.72%
Sulfate (as SO ₃)	Max. 4.0%	1.91%

PHYSICAL

Fineness:

Air permeability, Blaine	599 m ² /kg
Retained on No. 325 Sieve, max. 20%	3.2%

Granulated Blast Furnace Slag

Source: Blue Circle Atlantic, Inc.
P. O. Box 3
Ravena, New York 12143

Label: S-9 (Grade 120) and S-10 (Grade 100)

Origination: Sparrows Point Plant, Maryland

CHEMICAL ANALYSES, %

SiO ₂	35.33	35.51
Al ₂ O ₃	10.26	10.36
Fe ₂ O ₃	1.83	1.74
CaO	38.29	38.45
MgO	12.42	12.72
S	1.00	1.02
Na ₂ O	0.20	0.20
K ₂ O	0.38	0.38
Gain on ignition	0.60	1.00

FINENESS

325 Residue, %	3.0	5.7
Blaine, cm ² /g	5410	4170

51
Granulated Blast Furnace Slag

Source: C. T. Takahashi & Co., Inc.
Bay Vista Building, Suite 230
2815 Second Avenue
Seattle, Washington 98121

Label: S-11 (3720 Blaine)

Origination: Nippin Steel Chemical Co., Ltd., Japan

CHEMICAL COMPOSITION, %

Silicon dioxide (SiO ₂)	33.0
Aluminum oxide (Al ₂ O ₃)	14.6
Ferric oxide (Fe ₂ O ₃)	0.6
Calcium oxide (CaO)	41.1
Magnesium oxide (MgO)	6.7
Sulfur (S)	<u>0.8</u>
Total	96.8

PHYSICAL PROPERTIES

Specific gravity	2.90
Fineness, cm ² /g	3720

Granulated Blast Furnace Slag

Source: C. T. Takahashi & Co., Inc.
Bay Vista Building, Suite 230
2815 Second Avenue
Seattle, Washington 98121

Label: S-12 (5060 Blaine)

Origination: Nippon Steel Chemical Co., Ltd., Japan

CHEMICAL COMPOSITION, %

Silicon dioxide (SiO_2)	34.6
Aluminum oxide (Al_2O_3)	14.3
Ferric oxide (Fe_2O_3)	0.2
Calcium oxide (CaO)	41.2
Magnesium oxide (MgO)	6.8
Sulfur (S)	<u>0.7</u>
Total	97.8

PHYSICAL PROPERTIES

Specific gravity	2.90
Fineness, cm^2/g	5060

53
Granulated Blast Furnace Slag

Source: Standard Slag Cement
360 Jones Road
Fruitland, Ontario LOR 1LO

Label: S-13 (3910 Blaine)

Origination: Hamilton, Ontario

Typical Analysis, %			Typical Range in Analysis, %		
Calcium	(CaO)	36.66	Calcium	(CaO)	33-44
Alumina	(Al ₂ O ₃)	10.49	Alumina	(Al ₂ O ₃)	9-12
Silica	(SiO ₂)	35.37	Silica	(SiO ₂)	33-38
Magnesia	(MgO)	13.4	Magnesia	(MgO)	12-16.5
Ferrous oxide	(Fe ₂ O ₃)	0.96	Ferrous oxide	(Fe ₂ O ₃)	0.5-1.9
Manganese	(MnO)	0.64	Manganese	(MnO)	0.3-1.0
Sulphur (Total)	(S)	1.50	Sulfur (Total)	(S)	1.0-2.3
Trace elements and loss on ignition	±	1.13			

Granulated Blast Furnace Slag

Source: Standard Slag Cement
360 Jones Road
Fruitland, Ontario LOR 1LO

Label: S-14

Origination: Hamilton, Ontario. (Ground in laboratory of the Standard Slag Company.)

Typical Analysis, %			Typical Range in Analysis, %		
Calcium	(CaO)	36.66	Calcium	(CaO)	33-44
Alumina	(Al ₂ O ₃)	10.49	Alumina	(Al ₂ O ₃)	9-12
Silica	(SiO ₂)	35.37	Silica	(SiO ₂)	33-38
Magnesia	(MgO)	13.4	Magnesia	(MgO)	12-16.5
Ferrous oxide	(Fe ₂ O ₃)	0.96	Ferrous oxide	(Fe ₂ O ₃)	0.5-1.9
Manganese	(MnO)	0.64	Manganese	(MnO)	0.3-1.0
Sulphur (Total)	(S)	1.50	Sulfur (Total)	(S)	1.0-2.3
Trace elements and loss on ignition	±	1.13			

Appendix B: ADDITIONAL MATERIAL CHARACTERIZATION DATA

Table B.1. Density of matrix materials^a

Material	Density (g/cm ³)		
	Replicate measurements		Average
C-88	3.176	3.184	3.18
P-55	2.183	2.178	2.18
P-56	2.336	2.341	2.34
S-6	2.896	2.889	2.89
S-7	2.896	2.889	2.89
S-8	2.869	2.896	2.88
S-9	2.909	2.909	2.91
S-10	2.903	2.909	2.91
S-11	2.896	2.909	2.90
S-12	2.896	2.896	2.90
S-13			
S-14			

^aDetermined by ASTM C188-84.

Table B.2. Hydraulic activity of S-6 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-61	1486
S-62	1548
S-63	1593
S-64	1596
S-65	1596
S-66	1405
Average	1537 $\pm$ 78

Table B.3. Hydraulic activity of S-7 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-71	1698
S-72	1765
S-73	1868
S-74	1843
S-75	1900
S-76	1913
Average	1831 $\pm$ 84

Table B.4. Hydraulic activity of S-8 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-82	2171
S-83	2338
S-84	2088
S-85	2334
S-86	2326
Average	2251 $\pm$ 115

Table B.5. Hydraulic activity of S-9 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-91	2291
S-92	2245
S-93	2571
S-94	2244
S-95	2314
S-96	2366
Average	2355 $\pm$ 122

Table B.6. Hydraulic activity of S-10 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-101	1498
S-102	1558
S-104	1435
S-105	1456
S-106	1509
Average	1491 $\pm$ 48

Table B.7. Hydraulic activity of S-11 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-111	2480
S-112	2550
S-113	2545
S-114	2510
S-115	2523
S-116	2635
Average	2541 $\pm$ 53

Table B.8. Hydraulic activity of S-12 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-121	2508
S-122	2595
S-123	2543
S-124	2445
S-125	2490
S-126	2505
Average	2514 $\pm$ 51

Table B.9. Hydraulic activity of S-13 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-131	2028
S-132	1728
S-133	1940
S-134	1918
S-135	1950
S-136	1785
Average	1892 $\pm$ 112

Table B.10. Hydraulic activity of S-14 by reaction with alkali

Sample No.	Unconfined compressive strength (psi)
S-141	1373
S-142	1283
S-143	1378
S-144	1230
S-145	1390
S-146	1258
Average	1319 $\pm$ 70

Table B.11. Blaine fineness determinations^a

Blaine fineness (cm ³ /g)					
Material	Replicate measurements			Average	Standard deviation
C-88	3779.6	3791.6	3791.6	3788	6
S-6	5170.0	5194.9	5170.0	5178	14
S-7	6296.0	6263.0	6260.9	6273	20
S-8	5684.0	5659.0		5672	18
S-9	5411.0	5668.0	5646.0	5657	16
S-10	3922.0	4083.0	3955.0	4019	91
S-11	4271.1	4289.2		4280	13
S-12	5045.4	5035.2		5040	7

^aASTM test method C204-84.

Table B.12. Isothermal calorimetric data at 80°C for matrix components mixed with 101-AW at 9 lb/gal

Material	Total heat release (cal/g)				Standard deviation
	Replicate measurements			Average	
C-88	76.1	79.7	70.5	75.4	3.8
P-55	73.8	70.1	64.3	69.4	3.9
P-56	75.7	74.3	79.3	76.4	2.1
S-6	104.3	96.7	97.9	99.6	3.3
S-7	112.6	105.8	104.9	107.8	3.4
S-8	102.7	120.7	107.3	110.2	7.6
S-9	108.8	117.2	107.2	111.1	4.4
S-10	86.9	87.6	94.7	89.7	3.5
S-11	105.4	112.9	114.7	111.0	4.0
S-12	108.6	102.2	119.9	110.2	7.3

Appendix C. GROUT FORMULATIONS USED IN EXPERIMENTAL MATRIXES

Table C-1. Grout formulations used in Matrix 1^a

Run No.	Corresponding Observation No.	Blend composition (wt %)				Mix Ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX1-1	5	44.51	25.52	25.52	4.45	9.5
MX1-2	2	37.66	26.38	32.19	3.77	9.5
MX1-3	4	35.31	30.19	30.19	4.32	8.5
MX1-4	3	37.66	32.19	26.38	3.77	9.5
MX1-5	7	42.47	29.71	24.35	3.47	8.5
MX1-6	8	40.02	27.99	27.99	4.0	9.5
MX1-7	1	30.63	27.76	27.76	4.84	8.5
MX1-8	9	40.0	28.0	28.06	4.0	9.0
MX1-9	6	42.47	24.35	29.71	3.47	8.5

^aMaterials: limestone, P-59; fly ash, P-55; cement, C-88; and slag, S-8.

Table C-2 . Grout formulations used in Matrix 2^a

Run No.	Blend composition (wt %)				Mix ratio (lb/gal)
	Limestone	Fly ash	BFS	Cement	
MX2-1	37.66	26.38	32.19	3.77	9.5
MX2-2	42.47	24.35	29.71	3.47	8.5
MX2-3	42.47	29.71	24.35	3.47	8.5
MX2-4	44.51	25.52	25.52	4.45	9.5
MX2-5	40.0	28.0	28.0	4.0	9.0
MX2-6	35.31	30.19	30.19	4.32	8.5
MX2-7	40.02	27.99	27.99	4.0	9.5
MX2-8	39.63	27.76	27.76	4.84	8.5
MX2-9	37.66	32.19	26.38	3.77	9.5

^aMaterials: limestone, P-59; fly ash, P-55; cement, C-88; and slag, S-10.

Table C-3. Grout formulations used in Matrix 3^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX3-1	5	44.51	25.52	25.52	4.45	9.5
MX3-2	9	40.0	28.0	28.0	4.0	9.0
MX3-3	8	40.02	27.99	27.99	4.0	9.5
MX3-4	4	35.31	30.19	30.19	4.32	8.5
MX3-5	3	37.66	32.19	26.38	3.77	9.5
MX3-6	2	37.66	26.38	32.19	3.77	9.5
MX3-7	7	42.47	29.71	24.35	3.47	8.5
MX3-8	1	39.63	29.76	27.76	4.84	8.5
MX3-9	6	42.47	24.35	29.71	3.47	8.5

^aMaterials: limestone, P-60; fly ash, P-55; cement, C-88; and slag, S-9.

Table C-4. Grout formulations used in Matrix 4^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX4-1	9	40.0	28.0	28.0	4.0	9.0
MX4-2	2	37.66	26.38	32.19	3.77	9.5
MX4-3	5	44.51	25.52	25.52	4.45	9.5
MX4-4	8	40.02	27.99	27.99	4.0	9.5
MX4-5	1	39.63	27.76	27.76	4.84	8.5
MX4-6	7	42.47	29.71	24.35	3.47	8.5
MX4-7	4	35.31	30.19	30.19	4.32	8.5
MX4-8	3	37.66	32.19	26.38	3.77	9.5
MX4-9	6	42.47	24.35	29.71	3.47	8.5

^aMaterials: limestone, P-60; fly ash, P-62; cement, C-88; and slag, S-6.

Table C-5. Grout formulations used in Matrix 5

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX5-1	5	44.51	25.52	25.52	4.45	9.5
MX5-2	7	42.47	29.71	24.35	3.47	8.5
MX5-3	1	39.63	27.76	27.76	4.84	8.5
MX5-4	4	35.31	30.19	30.19	4.32	8.5
MX5-5	3	37.66	32.19	26.38	3.77	9.5
MX5-6	8	40.02	27.99	27.99	4.0	9.5
MX5-7	2	37.66	26.38	32.19	3.77	9.5
MX5-8	9	40.0	28.0	28.0	4.0	9.0
MX5-9	6	42.47	24.35	29.71	3.47	8.5

*Materials: limestone, P-60; fly ash, P-62; cement, C-88; and BFS, S-7.

Table C-6. Grout formulations used in Matrix 6*

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX6-1	8	40.02	27.99	27.99	4.0	9.5
MX6-2	4	35.31	30.19	30.19	4.32	8.5
MX6-3	2	37.66	26.38	32.19	3.77	9.5
MX6-4	3	37.66	32.19	26.38	3.77	9.5
MX6-5	7	42.47	29.71	24.35	3.47	8.5
MX6-6	1	39.63	27.76	27.76	4.84	8.5
MX6-7	9	40.0	28.0	28.0	4.0	9.0
MX6-8	6	42.47	24.35	29.71	3.47	8.5
MX6-9	5	44.51	25.52	25.52	4.45	9.5

*Materials: limestone, P-60; fly ash, P-62; cement, C-88; and BFS, S-13.

Table C-7. Grout formulations used in Matrix 7^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX7-1	8	40.02	27.99	27.99	4.0	9.5
MX7-2	5	44.51	25.52	25.52	4.45	9.5
MX7-3	9	40.0	28.0	28.0	4.0	9.0
MX7-4	7	42.47	29.71	24.35	3.47	8.5
MX7-5	4	35.31	30.19	30.19	4.32	8.5
MX7-6	2	37.66	26.38	32.19	3.77	9.5
MX7-7	6	42.47	24.35	29.71	3.47	8.5
MX7-8	3	37.66	32.19	26.38	3.77	9.5
MX7-9	1	39.63	27.76	27.76	4.84	8.5

^aMaterials: limestone, Jim Bridger ash, cement Type I-II-LA, and slag S-13.

Table C-8. Grout formulations used in Matrix 8^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX8-1	8	40.02	27.99	27.99	4.0	9.5
MX8-2	4	35.31	30.19	30.19	4.32	8.5
MX8-3	5	44.51	25.52	25.52	4.45	9.5
MX8-4	9	40.0	28.0	28.0	4.0	9.0
MX8-5	6	42.47	24.35	29.71	3.47	8.5
MX8-6	7	42.47	29.71	24.35	3.47	8.5
MX8-7	1	39.63	27.76	27.76	4.84	8.5
MX8-8	3	37.66	32.19	26.38	3.77	9.5
MX8-9	2	37.66	26.38	32.19	3.77	9.5

^aMaterials: limestone flour, Jim Bridger ash, Cement Type I-II-LA, and slag S-7.

Table C-9. Grout formulations used in Matrix 9*

Run No.	Corresponding observation No.	Blend composition (wt. %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX9-1	5	44.51	25.52	25.52	4.45	9.5
MX9-2	1	39.63	27.76	27.76	4.84	8.5
MX9-3	7	42.47	29.71	24.35	3.47	8.5
MX9-4	2	37.66	26.38	32.19	3.77	9.5
MX9-5	9	40.0	28.0	28.0	4.0	9.0
MX9-6	4	35.31	30.19	30.19	4.32	8.5
MX9-7	8	40.02	27.99	27.99	4.0	9.5
MX9-8	6	42.47	24.35	29.71	3.47	8.5
MX9-9	3	37.66	32.19	26.38	3.77	9.5

*Materials: limestone flour, Jim Bridger ash, cement Type I-II-LA, and slag S-14.

Table C-10. Grout formulations used in Matrix 10^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX10-1	9	40.0	28.0	28.0	4.0	9.0
MX10-2	2	37.66	26.38	32.19	3.77	9.5
MX10-3	5	44.51	25.52	25.52	4.45	9.5
MX10-4	8	40.02	27.99	27.99	4.0	9.5
MX10-5	1	39.63	27.76	27.76	4.84	8.5
MX10-6	7	42.47	29.71	24.35	3.47	8.5
MX10-7	4	35.31	30.19	30.19	4.32	8.5
MX10-8	3	37.66	32.19	26.38	3.77	9.5
MX10-9	6	42.47	24.35	29.71	3.47	8.5

^aMaterials: limestone ground, Centralia fly ash, cement Type I-II-LA, and slag S-6.

Table C-11. Grout formulations used in Matrix 11^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX11-1	9	40.0	28.0	28.0	4.0	9.0
MX11-2	2	37.66	26.38	32.19	3.77	9.5
MX11-3	5	44.51	25.52	25.52	4.45	9.5
MX11-4	8	40.02	27.99	27.99	4.0	9.5
MX11-5	7	42.47	29.71	24.35	3.47	8.5
MX11-6	4	35.31	30.19	30.19	4.32	8.5
MX11-7	3	37.66	32.19	26.38	3.77	9.5
MX11-8	1	39.63	27.76	27.76	4.84	8.5
MX11-9	6	42.47	24.35	29.71	3.47	8.5

^aMaterials: ground limestone, Jim Bridger fly ash, cement Type I-II-LA, and slag S-14.

Table C-12. Grout formulations used in Matrix 12*

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX12-1	8	40.02	27.99	27.99	4.0	9.5
MX12-2	1	39.63	27.76	27.76	4.84	8.5
MX12-3	7	42.47	29.71	24.35	3.47	8.5
MX12-4	9	40.0	28.0	28.0	4.0	9.0
MX12-5	3	37.66	32.19	26.38	3.77	9.5
MX12-6	2	37.66	26.38	32.19	3.77	9.5
MX12-7	5	44.51	25.52	25.52	4.45	9.5
MX12-8	6	42.47	24.35	29.71	3.47	8.5
MX12-9	4	35.31	30.19	30.19	4.32	8.5

*Materials: limestone flour, Centralia ash, slag S-8, and Type I-II cement from LaFarge Corp.

Table C-13. Grout formulations used in Matrix 13^a

Run No.	Corresponding observation No.	Blend composition (wt %)				Mix ratio (lb/gal)
		Limestone	Fly ash	BFS	Cement	
MX13-1	2	37.66	26.38	32.19	3.77	9.5
MX13-2	7	42.47	29.71	24.35	3.47	8.5
MX13-3	5	44.51	25.52	25.52	4.45	9.5
MX13-4	3	37.66	32.19	26.38	3.77	9.5
MX13-5	6	42.47	24.35	29.71	3.47	8.5
MX13-6	8	40.02	27.99	27.99	4.0	9.5
MX13-7	4	35.31	30.19	30.19	4.32	8.5
MX13-8	1	39.63	27.76	27.76	4.84	8.5
MX13-9	9	40.0	28.0	28.0	4.0	9.0

^aMaterials: limestone flour, Centralia ash, slag S-11, and Type I-II cement from LaFarge Corp.

Appendix D. FLUID-GROUT DATA FOR ALL EXPERIMENTAL RUNS

Table D-1. Properties of fluid grouts prepared from Matrix 1

	Corresponding observation No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX1-1-A	5	14.7	5.7	2.0	5.6	13.5
MX1-1-B		15.0	5.7	1.9	5.2	13.5
MX1-1-C		14.7	5.6	2.4	6.7	13.4
MX1-2-A	2	15.5	5.7	3.5	9.5	13.5
MX1-2-B		15.8	5.7	3.0	8.1	13.5
MX1-2-C		15.1	5.7	3.1	8.5	13.5
MX1-3-A	4	12.5	5.5	2.6	7.0	13.2
MX1-3-B		19.8	5.5	2.4	6.5	13.2
MX1-3-C		14.0	5.5	2.6	7.0	13.2
MX1-4-A	3	15.6	5.6	2.5	6.8	13.3
MX1-4-B		14.5	5.6	2.6	7.0	13.3
MX1-4-C		14.4	5.6	2.5	6.8	13.4
MX1-5-A	7	12.7	5.5	1.6	4.5	13.2
MX1-5-B		12.7	5.5	1.6	4.5	13.2
MX1-5-C		13.9	5.5	1.9	5.2	13.2
MX1-6-A	8	15.4	5.7	2.4	6.5	13.5
MX1-6-B		15.6	5.7	2.0	5.5	13.5
MX1-6-C		15.0	5.7	2.4	6.5	13.5
MX1-7-A	1	13.2	5.5	2.0	5.5	13.2
MX1-7-B		13.5	5.5	2.0	5.5	13.2
MX1-7-C		13.2	5.5	2.4	6.5	13.2
MX1-8-A	9	13.4	5.6	2.1	5.8	13.3
MX1-8-B		14.8	5.6	2.3	6.2	13.3
MX1-8-C		14.6	5.6	2.4	6.5	13.4
MX1-9-A	6	12.7	5.6	12.4	34.0	13.3
MX1-9-B		13.8	5.6	35.0	96.0	13.3
MX1-9-C		13.3	5.6	5.6	15.5	13.3

Table D-2. Properties of fluid grouts prepared from Matrix 2

Run No.	Corresponding observation No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX2-1-A	8	13.7	5.7	2.4	6.5	13.6
MX2-1-B		13.6	5.7	2.4	6.5	13.6
MX2-1-C		12.6	5.7	2.2	6.0	13.6
MX2-2-A	1	11.9	5.6	1.6	4.5	13.3
MX2-2-B		11.9	5.6	2.2	6.0	13.3
MX2-2-C		12.0	5.6	2.2	6.0	13.3
MX2-3-A	9	12.4	5.6	2.6	7.0	13.2
MX2-3-B		12.2	5.6	2.6	7.0	13.3
MX2-3-C		12.4	5.6	2.7	7.5	13.3
MX2-4-A	6	14.6	5.7	4.4	12.0	13.6
MX2-4-B		14.3	5.7	4.0	11.0	13.6
MX2-4-C		14.1	5.7	4.2	11.5	13.6
MX2-5-A	4	13.2	5.7	3.1	8.5	13.6
MX2-5-B		14.4	5.7	4.9	13.5	13.5
MX2-5-C		14.0	5.7	3.8	10.5	13.5
MX2-6-A	2	13.5	5.6	1.8	5.0	13.3
MX2-6-B		12.4	5.6	1.6	4.5	13.3
MX2-6-C		12.4	5.6	1.5	4.2	13.4
MX2-7-A	3	14.5	5.7	2.6	7.0	13.6
MX2-7-B		14.7	5.7	2.0	5.5	13.6
MX2-7-C		13.9	5.7	2.3	6.2	13.6
MX2-8-A	7	13.5	5.6	3.3	9.0	13.4
MX2-8-B		13.5	5.6	3.6	10.0	13.4
MX2-8-C		14.0	5.7	4.2	11.4	13.5
MX2-9-A	5	15.6	5.8	5.5	15.0	13.7
MX2-9-B		15.8	5.8	6.9	19.0	13.7
MX2-9-C		15.9	5.7	6.0	16.5	13.7

Table D-3. Properties of fluid grouts prepared from Matrix 2R

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX2R-1-A	14.4	5.6	1.6	4.5	13.4
MX2R-1-B	14.4	5.6	1.3	3.5	13.4
MX2R-1-C	14.1	5.6	1.6	4.5	13.4
MX2R-2-A	12.1	5.5	1.3	3.5	13.1
MX2R-2-B	12.4	5.5	1.3	3.5	13.1
MX2R-2-C	11.2	5.5	1.3	3.5	13.1
MX2R-3-A	11.6	5.5	1.1	3.0	13.0
MX2R-3-B	12.7	5.5	1.3	3.5	13.1
MX2R-3-C	12.4	5.5	1.1	3.0	13.0
MX2R-4-A	15.0	5.6	2.0	5.5	13.4
MX2R-4-B	14.9	5.6	1.6	4.5	13.4
MX2R-4-C	15.1	5.6	1.8	5.0	13.4
MX2R-5-A	13.5	5.6	1.3	3.5	13.2
MX2R-5-B	14.5	5.5	1.3	3.5	13.2
MX2R-5-C	14.2	5.6	1.3	3.5	13.2
MX2R-6-A	13.9	5.5	1.3	3.5	13.0
MX2R-6-B	13.8	5.5	1.3	3.5	13.0
MX2R-6-C	11.9	5.5	1.1	3.0	13.0
MX2R-7-A	15.3	5.6	1.6	4.5	13.4
MX2R-7-B	14.3	5.6	1.8	5.0	13.4
MX2R-7-C	14.7	5.6	1.6	4.5	13.4
MX2R-8-A	13.5	5.5	1.5	4.0	13.1
MX2R-8-B	12.9	5.5	1.1	3.0	13.1
MX2R-8-C	12.6	5.5	1.3	3.5	13.1
MX2R-9-A	14.4	5.6	1.6	4.5	13.4
MX2R-9-B	14.2	5.6	1.6	4.5	13.4
MX2R-9-C	14.3	5.6	1.5	4.0	13.4

Table D-4. Properties of fluid grouts prepared from Matrix 3

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX3-1-A	14.9	5.7	5.6	15.5	13.6
MX3-1-B	15.3	5.7	5.1	14.0	13.6
MX3-1-C	15.4	5.7	5.5	15.0	13.5
MX3-2-A	14.6	5.6	4.4	12.0	13.4
MX3-2-B	14.0	5.6	5.1	14.0	13.4
MX3-2-C	13.8	5.6	4.7	13.0	13.4
MX3-3-A	14.7	5.7	8.4	23.0	13.6
MX3-3-B	15.3	5.7	5.3	14.5	13.6
MX3-3-C	15.0	5.7	6.9	19.0	13.6
MX3-4-A	13.8	5.6	5.5	15.0	13.3
MX3-4-B	13.0	5.6	4.4	12.0	13.3
MX3-4-C	13.8	5.6	3.8	10.5	13.3
MX3-5-A	16.1	5.7	5.6	15.5	13.5
MX3-5-B	16.2	5.7	4.7	13.0	13.5
MX3-5-C	15.7	5.7	4.7	13.0	13.5
MX3-6-A	16.7	5.7	8.7	24.0	13.7
MX3-6-B	17.1	5.7	9.1	25.0	13.7
MX3-6-C	17.2	5.7	8.2	22.5	13.6
MX3-7-A	15.2	5.6	4.9	13.5	13.2
MX3-7-B	14.2	5.6	4.9	13.5	13.3
MX3-7-C	14.0	5.6	5.5	15.0	13.3
MX3-8-A	14.9	5.6	8.0	22.0	13.4
MX3-8-B	14.6	5.6	6.7	18.0	13.4
MX3-8-C	14.2	5.6	5.6	15.5	13.4
MX3-9-A	15.2	5.7	4.2	11.5	13.5
MX3-9-B	14.2	5.7	2.7	7.5	13.5
MX3-9-C	15.1	5.7	2.9	8.0	13.5

Table D-5. Properties of fluid grouts prepared from Matrix 4

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX4-1-A	14.7	5.6	2.6	7.0	13.3
MX4-1-B	14.5	5.6	2.2	6.0	13.4
MX4-1-C	14.9	5.6	2.2	6.0	13.4
MX4-2-A	16.0	5.7	2.6	7.0	13.6
MX4-2-B	16.1	5.7	2.4	6.5	13.6
MX4-2-C	16.6	5.7	2.0	5.5	13.5
MX4-3-A	16.0	5.7	2.6	7.0	13.6
MX4-3-B	16.4	5.7	2.0	5.5	13.6
MX4-3-C	16.2	5.7	2.0	5.5	13.6
MX4-4-A	16.6	5.6	2.4	6.5	13.4
MX4-4-B	16.8	5.7	2.6	7.0	13.5
MX4-4-C	16.4	5.7	2.0	5.5	13.5
MX4-5-A	14.6	5.6	1.6	4.5	13.3
MX4-5-B	14.3	5.6	1.6	4.5	13.3
MX4-5-C	14.1	5.6	1.6	4.5	13.3
MX4-6-A	13.2	5.5	1.6	4.5	13.2
MX4-6-B	13.5	5.6	1.5	4.0	13.3
MX4-6-C	12.5	5.6	1.3	3.5	13.2
MX4-7-A	14.4	5.6	1.6	4.5	13.3
MX4-7-B	13.7	5.6	1.6	4.5	13.2
MX4-7-C	13.8	5.6	1.6	4.5	13.3
MX4-8-A	15.1	5.7	2.6	7.0	13.5
MX4-8-B	15.5	5.7	2.2	6.0	13.5
MX4-8-C	15.6	5.7	2.0	5.5	13.5
MX4-9-A	14.1	5.6	1.5	4.0	13.2
MX4-9-B	14.1	5.6	2.4	6.5	13.3
MX4-9-C	14.2	5.6	2.4	6.5	13.3

Table D-6. Properties of fluid grouts prepared from Matrix 5

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX5-1-A	16.8	5.6	2.4	6.5	13.4
MX5-1-B	16.9	5.6	2.0	5.5	13.4
MX5-1-C	16.8	5.6	1.8	5.0	13.4
MX5-2-A	15.0	5.5	1.6	4.5	13.1
MX5-2-B	14.2	5.5	1.6	4.5	13.1
MX5-2-C	14.4	5.5	1.5	4.0	13.1
MX5-3-A	14.4	5.5	1.8	5.0	13.1
MX5-3-B	14.5	5.5	1.8	5.0	13.1
MX5-3-C	14.9	5.5	1.6	4.5	13.1
MX5-4-A	14.9	5.5	1.3	3.5	13.2
MX5-4-B	16.3	5.5	2.0	5.5	13.2
MX5-4-C	16.5	5.5	1.6	4.5	13.1
MX5-5-A	15.8	5.6	2.2	6.0	13.4
MX5-5-B	16.0	5.6	2.0	5.5	13.4
MX5-5-C	16.6	5.6	2.0	5.5	13.4
MX5-6-A	16.5	5.6	2.0	5.5	13.4
MX5-6-B	16.5	5.6	2.4	6.5	13.4
MX5-6-C	17.1	5.6	2.4	6.5	13.4
MX5-7-A	18.0	5.6	2.4	6.5	13.5
MX5-7-B	17.3	5.6	2.6	7.0	13.4
MX5-7-C	18.0	5.6	2.6	7.0	13.4
MX5-8-A	16.3	5.6	2.2	6.0	13.4
MX5-8-B	16.4	5.6	2.4	6.5	13.4
MX5-8-C	16.0	5.6	2.6	7.0	13.4
MX5-9-A	15.1	5.6	1.8	5.0	13.3
MX5-9-B	14.8	5.6	1.8	5.0	13.3
MX5-9-C	15.4	5.6	1.6	4.5	13.3

Table D-7. Properties of fluid grouts prepared from Matrix 6

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX6-1-A	18.1	5.6	2.6	7.2	13.4
MX6-1-B	17.3	5.6	2.7	7.5	13.4
MX6-1-C	18.3	5.6	3.1	8.5	13.4
MX6-2-A	16.9	5.5	2.4	6.5	13.1
MX6-2-B	15.4	5.5	1.6	4.5	13.1
MX6-2-C	15.5	5.5	2.0	5.5	13.1
MX6-3-A	19.3	5.6	2.4	6.5	13.4
MX6-3-B	17.8	5.6	2.0	5.5	13.4
MX6-3-C	18.3	5.6	1.8	5.0	13.4
MX6-4-A	17.8	5.6	2.6	7.0	13.3
MX6-4-B	17.9	5.6	2.2	6.0	13.3
MX6-4-C	17.0	5.6	2.4	6.5	13.3
MX6-5-A	15.0	5.5	1.5	4.0	13.0
MX6-5-B	14.4	5.5	1.5	4.0	13.0
MX6-5-C	15.1	5.5	2.0	5.5	13.0
MX6-6-A	14.4	5.5	2.2	6.0	13.1
MX6-6-B	14.7	5.5	2.0	5.5	13.1
MX6-6-C	14.3	5.5	1.6	4.5	13.1
MX6-7-A	17.0	5.6	1.8	5.0	13.3
MX6-7-B	15.5	5.6	1.6	4.5	13.2
MX6-7-C	15.8	5.6	1.6	4.5	13.2
MX6-8-A	15.2	5.5	1.3	4.5	13.2
MX6-8-B	14.8	5.5	1.5	4.0	13.2
MX6-8-C	15.3	5.5	1.6	4.5	13.2
MX6-9-A	17.4	5.6	2.4	6.5	13.4
MX6-9-B	15.4	5.6	2.4	6.5	13.4
MX6-9-C	16.6	5.6	2.4	6.5	13.4

Table D-8. Properties of fluid grouts prepared from Matrix 7

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX7-1-A	19.4	5.7	2.4	6.5	13.5
MX7-1-B	17.4	5.7	2.6	7.0	13.5
MX7-1-C	17.9	5.6	2.6	7.0	13.5
MX7-2-A	17.8	5.7	2.4	6.5	13.5
MX7-2-B	18.4	5.7	2.6	7.0	13.5
MX7-2-C	17.8	5.7	2.9	8.0	13.5
MX7-3-A	18.0	5.6	2.0	5.5	13.4
MX7-3-B	18.5	5.6	2.2	6.0	13.4
MX7-3-C	18.0	5.6	1.8	5.0	13.3
MX7-4-A	16.1	5.5	1.6	4.5	13.2
MX7-4-B	15.2	5.5	1.6	4.5	13.2
MX7-4-C	15.0	5.5	1.8	5.0	13.1
MX7-5-A	16.3	5.5	2.0	5.5	13.2
MX7-5-B	16.4	5.5	2.2	6.0	13.2
MX7-5-C	16.4	5.5	1.8	5.0	13.2
MX7-6-A	18.8	5.6	2.4	6.5	13.5
MX7-6-B	18.8	5.6	2.4	6.5	13.5
MX7-6-C	17.3	5.7	2.4	6.5	13.5
MX7-7-A	16.3	5.6	1.8	5.0	13.3
MX7-7-B	16.1	5.6	1.6	4.5	13.3
MX7-7-C	16.5	5.6	1.8	5.0	13.2
MX7-8-A	17.6	5.7	2.4	6.5	13.5
MX7-8-B	18.4	5.7	2.6	7.0	13.5
MX7-8-C	17.4	5.7	2.6	7.0	13.5
MX7-9-A	16.0	5.6	2.0	5.5	13.3
MX7-9-B	14.8	5.6	1.8	5.0	13.3
MX7-9-C	14.8	5.6	2.2	6.0	13.3

Table D-9. Properties of fluid grouts prepared from Matrix 8

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX8-1-A	16.3	5.6	2.4	6.5	13.4
MX8-1-B	16.8	5.6	2.4	6.5	13.4
MX8-1-C	17.0	5.6	2.2	6.0	13.4
MX8-2-A	16.8	5.5	1.8	5.0	13.1
MX8-2-B	14.7	5.5	1.8	5.0	13.2
MX8-2-C	16.6	5.5	1.6	4.5	13.1
MX8-3-A	17.6	5.6	1.8	5.0	13.4
MX8-3-B	17.3	5.6	1.8	5.0	13.4
MX8-3-C	16.9	5.6	1.8	5.0	13.4
MX8-4-A	16.9	5.6	1.6	4.5	13.3
MX8-4-B	16.8	5.6	1.5	4.0	13.3
MX8-4-C	16.0	5.6	1.6	4.5	13.3
MX8-5-A	16.2	5.5	1.6	4.5	13.2
MX8-5-B	15.4	5.5	1.6	4.5	13.2
MX8-5-C	15.4	5.5	1.8	5.0	13.2
MX8-6-A	14.7	5.5	1.5	4.0	13.1
MX8-6-B	15.0	5.5	1.1	3.0	13.1
MX8-6-C	14.8	5.5	1.5	4.0	13.1
MX8-7-A	16.4	5.5	1.8	5.0	13.2
MX8-7-B	16.1	5.5	1.8	5.0	13.2
MX8-7-C	15.9	5.5	1.8	5.0	13.2
MX8-8-A	16.2	5.6	2.6	7.0	13.5
MX8-8-B	17.2	5.6	2.6	7.0	13.4
MX8-8-C	17.8	5.6	2.4	6.5	13.5
MX8-9-A	18.0	5.7	2.4	6.5	13.5
MX8-9-B	17.4	5.7	9.1	25.0	13.5
MX8-9-C	17.2	5.7	2.4	6.5	13.5

Table D-10. Properties of fluid grouts prepared from Matrix 9

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX9-1-A	17.2	5.6	1.5	4.0	13.4
MX9-1-B	16.5	5.6	1.3	3.5	13.4
MX9-1-C	16.7	5.6	1.8	5.0	13.4
MX9-2-A	14.9	5.5	1.6	4.5	13.1
MX9-2-B	15.0	5.5	1.5	4.0	13.1
MX9-2-C	14.9	5.5	1.6	4.5	13.1
MX9-3-A	14.7	5.5	1.3	3.5	13.1
MX9-3-B	13.8	5.5	1.1	3.0	13.1
MX9-3-C	14.5	5.5	1.1	3.0	13.1
MX9-4-A	15.7	5.6	1.8	5.0	13.5
MX9-4-B	16.7	5.6	2.0	5.5	13.5
MX9-4-C	15.9	5.6	1.8	5.0	13.5
MX9-5-A	15.3	5.6	1.5	4.0	13.3
MX9-5-B	14.7	5.6	1.6	4.5	13.3
MX9-5-C	14.3	5.6	1.5	4.0	13.3
MX9-6-A	15.1	5.5	1.6	4.5	13.1
MX9-6-B	15.9	5.5	1.6	4.5	13.1
MX9-6-C	14.7	5.5	1.5	4.0	13.2
MX9-7-A	17.5	5.6	2.2	6.0	13.5
MX9-7-B	16.0	5.6	2.0	5.5	13.4
MX9-7-C	18.5	5.6	2.0	5.5	13.5
MX9-8-A	15.5	5.5	1.8	5.0	13.2
MX9-8-B	15.4	5.5	1.5	4.0	13.2
MX9-8-C	15.2	5.6	1.5	4.0	13.2
MX9-9-A	18.0	5.6	1.8	5.0	13.4
MX9-9-B	17.4	5.6	2.4	6.5	13.4
MX9-9-C	17.6	5.6	2.2	6.0	13.4

Table D-11. Properties of fluid grouts prepared from Matrix 10

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX10-1-A	15.8	5.5	1.3	3.5	13.2
MX10-1-B	15.4	5.5	1.5	4.0	13.2
MX10-1-C	14.3	5.5	1.1	3.0	13.1
MX10-2-A	17.4	5.6	1.6	4.5	13.3
MX10-2-B	16.8	5.6	1.8	5.0	13.3
MX10-2-C	16.8	5.6	1.6	4.5	13.3
MX10-3-A	16.8	5.6	1.6	4.5	13.3
MX10-3-B	15.8	5.6	1.6	4.5	13.3
MX10-3-C	16.3	5.6	1.5	4.0	13.3
MX10-4-A	16.6	5.6	1.3	3.5	13.3
MX10-4-B	16.2	5.6	1.6	4.5	13.3
MX10-4-C	16.8	5.6	1.5	4.0	13.3
MX10-5-A	14.4	5.5	1.3	3.5	13.1
MX10-5-B	15.1	5.5	1.5	4.0	13.1
MX10-5-C	14.5	5.5	1.3	3.5	13.1
MX10-6-A	14.1	5.5	1.3	3.5	13.1
MX10-6-B	13.6	5.5	1.3	3.5	13.0
MX10-6-C	14.5	5.5	1.3	3.5	13.0
MX10-7-A	14.8	5.5	1.3	3.5	13.1
MX10-7-B	14.9	5.5	1.3	3.5	13.1
MX10-7-C	14.1	5.5	1.5	4.0	13.1
MX10-8-A	15.9	5.6	1.5	4.0	13.3
MX10-8-B	15.6	5.6	1.5	4.0	13.3
MX10-8-C	15.0	5.6	1.6	4.5	13.3
MX10-9-A	14.3	5.5	1.3	3.5	13.1
MX10-9-B	14.8	5.5	1.3	3.5	13.1
MX10-9-C	14.9	5.5	1.3	3.5	13.1

Table D-12. Properties of fluid grouts prepared from Matrix 11

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX11-1-A	15.3	5.5	1.5	4.0	13.2
MX11-1-B	15.3	5.5	1.6	4.5	13.2
MX11-1-C	14.6	5.5	1.5	4.0	13.2
MX11-2-A	15.8	5.6	1.8	5.0	13.4
MX11-2-B	15.0	5.6	2.0	5.5	13.4
MX11-2-C	15.6	5.6	2.2	6.0	13.4
MX11-3-A	15.3	5.6	1.6	4.5	13.4
MX11-3-B	15.6	5.6	1.6	4.5	13.4
MX11-3-C	14.9	5.6	2.0	5.5	13.4
MX11-4-A	16.3	5.6	1.8	5.0	13.4
MX11-4-B	15.4	5.6	1.8	5.0	13.4
MX11-4-C	16.6	5.6	1.4	4.0	13.5
MX11-5-A	14.9	5.5	1.3	3.5	13.0
MX11-5-B	14.8	5.5	1.3	3.5	13.0
MX11-5-C	13.3	5.5	1.3	3.5	13.0
MX11-6-A	14.4	5.5	1.3	3.5	13.0
MX11-6-B	14.2	5.5	1.1	3.0	13.0
MX11-6-C	13.6	5.5	1.5	4.0	13.0
MX11-7-A	15.8	5.6	1.6	4.5	13.3
MX11-7-B	15.7	5.6	1.5	4.0	13.3
MX11-7-C	15.6	5.6	1.8	5.0	13.3
MX11-8-A	15.0	5.5	1.3	3.5	13.1
MX11-8-B	14.0	5.5	1.5	4.0	13.1
MX11-8-C	14.1	5.5	1.5	4.0	13.1
MX11-9-A	14.6	5.5	1.3	3.5	13.1
MX11-9-B	14.9	5.5	1.5	4.0	13.1
MX11-9-C	14.8	5.5	1.5	4.0	13.1

Table D-13. Properties of fluid grouts prepared from Matrix 12

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX12-1-A	16.4	5.6	2.7	7.5	13.3
MX12-1-B	15.2	5.6	3.1	8.5	13.3
MX12-1-C	16.1	5.6	2.9	8.0	13.3
MX12-2-A	14.8	5.5	1.6	4.5	13.0
MX12-2-B	13.9	5.5	2.0	5.5	13.0
MX12-2-C	14.4	5.5	2.0	5.5	13.0
MX12-3-A	14.6	5.4	1.6	4.5	12.9
MX12-3-B	14.1	5.4	1.8	5.0	13.0
MX12-3-C	13.3	5.4	1.8	5.0	12.9
MX12-4-A	15.8	5.5	2.0	5.5	13.1
MX12-4-B	15.4	5.5	2.2	6.0	13.1
MX12-4-C	15.8	5.5	2.2	6.0	13.1
MX12-5-A	16.2	5.5	3.1	8.5	13.2
MX12-5-B	16.3	5.5	2.6	7.0	13.2
MX12-5-C	16.0	5.5	2.9	8.0	13.2
MX12-6-A	17.6	5.6	3.6	10.0	13.3
MX12-6-B	17.1	5.6	3.6	10.0	13.3
MX12-6-C	17.9	5.6	3.1	8.5	13.3
MX12-7-A	16.6	5.6	3.3	9.0	13.3
MX12-7-B	16.8	5.6	3.5	9.5	13.3
MX12-7-C	16.5	5.6	3.1	8.5	
MX12-8-A	15.5	5.5	2.4	6.5	13.1
MX12-8-B	15.1	5.5	2.2	6.0	13.1
MX12-8-C	15.3	5.5	2.4	6.5	13.1
MX12-9-A	15.6	5.5	2.6	7.0	13.1
MX12-9-B	15.7	5.5	2.4	6.5	13.0
MX12-9-C	16.2	5.5	2.2	6.0	13.0

Appendix E. DRAINABLE-WATER DATA FOR ALL EXPERIMENTAL RUNS

Table E-1. Drainable-water values for grouts prepared from Matrix 1

Run No.	Corresponding observation No.	Drainable water (mL) observed at					
		2 h	1 d	7 d	14 d	21 d	28 d
MX1-1-A	5	11	12	10	8	8	8
MX1-1-B		17	20	16	16	16	15
MX1-1-C		12	14	10	10	10	10
MX1-2-A	2	12	14	11	10	10	10
MX1-2-B		9	10	6	7	6	6
MX1-2-C		7	8	4	6	4	3
MX1-3-A	4	14	14	14	10	10	10
MX1-3-B		13	13	11	10	10	7
MX1-3-C		14	15	13	10	10	8
MX1-4-A	3	12	12	12	8	7	8
MX1-4-B		10	9	8	6	5	5
MX1-4-C		11	10	6	6	6	5
MX1-5-A	7	18	18	16	14	14	14
MX1-5-B		17	17	15	14	14	14
MX1-5-C		18	18	18	16	14	15
MX1-6-A	8	10	10	9	8	6	5
MX1-6-B		10	9	9	6	5	5
MX1-6-C		12	12	12	10	8	8
MX1-7-A	1	18	18	16	13	14	14
MX1-7-B		13	14	12	10	10	10
MX1-7-C		21	21	17	17	16	17
MX1-8-A	9	11	11	9	8	8	7
MX1-8-B		10	9	9	8	6	5
MX1-8-C		12	11	11	9	8	9
MX1-9-A	6	27	54	52	52	52	52
MX1-9-B		21	56	54	54	54	54
MX1-9-C		23	53	52	51	52	51

Table E-2. Drainable-water values for grouts prepared from Matrix 2^a

Run No.	Corresponding observation No.	Drainable water (mL) observed at					
		2 h	1 d	7 d	14 d	21 d	28 d
MX2-1-A	8	20	22	18	18	18	18
MX2-1-B		25	31	29	29	26	27
MX2-1-C		18	18	15	14	14	14
MX2-2-A	1	36	47	14	45	44	44
MX2-2-B		36	49	46	47	46	46
MX2-2-C		28	51	49	47	47	46
MX2-3-A	9	34	49	46	46	45	44
MX2-3-B		35	52	48	48	46	46
MX2-3-C		36	52	50	48	48	46
MX2-4-A	6	30	39	36	35	35	35
MX2-4-B		24	28	27	25	25	25
MX2-4-C		32	40	38	35	36	36
MX2-5-A	4	30	40	36	36	36	35
MX2-5-B		27	43	40	39	40	40
MX2-5-C		26	44	36	41	40	40
MX2-6-A	2	35	39	35	34	33	34
MX2-6-B		30	31	28	27	26	27
MX2-6-C		30	30	26	26	26	26
MX2-7-A	3	22	26	21	22	19	19
MX2-7-B		21	18	16	16	15	16
MX2-7-C		23	24	21	20	20	20
MX2-8-A	7	28	41	36	36	36	35
MX2-8-B		29	42	37	36	36	36
MX2-8-C		28	43	42	42	42	42
MX2-9-A	5	26	36	30	30	30	30
MX2-9-B		24	28	24	22	22	22
MX2-9-C		21	44	42	38	40	39

^aBleed H₂O volumes were poured from the material used for rheology measurements and remixed with the remaining grout from initial mixing, for all specimens poured to date except MX2-9-C. This specimen was poured from the rheology cup only. As solids are retained on the viscometer BOB after measurement, it is likely that this is the cause of the increased VOC of bleed water.

Table E-3. Drainable-water values for grouts prepared from Matrix 2R

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX2R-1-A	10	9 ^a	8 ^a	6 ^a	4 ^a	2 ^a
MX2R-1-B	10	8	8	7	5	5
MX2R-1-C	9	10	9	8	8	4 ^a
MX2R-2-A	30	32	31	30	30	30
MX2R-2-B	28	34	34	33	33	32
MX2R-2-C	26	28	28	27	27	26
MX2R-3-A	30	36	36	36	36	37
MX2R-3-B	30	36	36	36	36	36
MX2R-3-C	32	33	32	32	32	32
MX2R-4-A	18	22	18	18	18	18
MX2R-4-B	18	21	18	18	18	18
MX2R-4-C	17	17	16	16	15	15
MX2R-5-A	21	22	22	22	21	21
MX2R-5-B	24	26	24	23	22	21
MX2R-5-C	24	26	23	22	23	21
MX2R-6-A	30	32	31	30	29	29
MX2R-6-B	31	32	29	29	30	27
MX2R-6-C	32	32	31	30	30	30
MX2R-7-A	19	18	18	16	16	16
MX2R-7-B	20	19	18	15	15	14
MX2R-7-C	22	22	20	18	18	18
MX2R-8-A	24	26	22	21	21	21
MX2R-8-B	23	26	21	20	20	19
MX2R-8-C	24	29	28	26	26	26
MX2R-9-A	19	18	16	14	14	13
MX2R-9-B	19	18	16	16	15	15
MX2R-9-C	18	16	14	12	12	12

^aCylinder leaked.

Table E-4. Drainable-water values for grouts prepared from Matrix 3

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX3-1-A	24	32	27	27	26	26
MX3-1-B	13	18	13	12	13	13
MX3-1-C	17	23	17	18	17	16
MX3-2-A	24	26	23	22	22	20
MX3-2-B	18	22	18	16	16	15
MX3-2-C	31	36	34	33	32	31
MX3-3-A	25	23	21	20	20	20
MX3-3-B	12	13	8	9	8	8
MX3-3-C	12	13	12	12	11	10
MX3-4-A	30	32	30	28	28	29
MX3-4-B	31	35	33	33	33	33
MX3-4-C	29	37	33	34	33	32
MX3-5-A	26	29	27	26	26	26
MX3-5-B	23	23	22	21	20	20
MX3-5-C	18	19	17	16	16	16
MX3-6-A	12	20	18	18	18	18
MX3-6-B	22	25	23	24	24	24
MX3-6-C	13	23	21	20	19	20
MX3-7-A	14	48	45	45	45	45
MX3-7-B	25	41	38	39	38	38
MX3-7-C	28	47	36	36	36	36
MX3-8-A	25	35	32	32	33	32
MX3-8-B	26	28	27	26	26	26
MX3-8-C	22	33	30	29	30	29
MX3-9-A	23	26	24	22	22	22
MX3-9-B	16	18	15	14	14	14
MX3-9-C	22	25	22	22	22	22

Table E-5. Drainable-water values for grouts prepared from Matrix 4

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX4-1-A	24	27	24	24	24	24
MX4-1-B	25	26	24	24	24	24
MX4-1-C	14	14	11	11	11	10
MX4-2-A	14	15	12	11	10	10
MX4-2-B	11	12	8	8	7	6
MX4-2-C	10	10	7	6	5	5
MX4-3-A	12	10	6	5	2 ^a	0 ^a
MX4-3-B	15	14	11	11	10	10
MX4-3-C	15	16	14	14	12	12
MX4-4-A	14	14	10	10	10	8
MX4-4-B	10	10	7	6	5	4
MX4-4-C	12	10	6	6	6	4
MX4-5-A	20	22	20	18	18	18
MX4-5-B	18	21	20	18	18	17
MX4-5-C	14	16	13	12	12	12
MX4-6-A	25	30	28	28	27	26
MX4-6-B	26	32	32	30	30	30
MX4-6-C	27	30	28	28	28	27
MX4-7-A	21	23	19	18	18	18
MX4-7-B	21	23	19	18	18	18
MX4-7-C	18	21	17	16	16	16
MX4-8-A	12	11	8	8	8	8
MX4-8-B	8	10	4	4	4	4
MX4-8-C	14	14	12	12	12	12
MX4-9-A	19	21	18	17	17	17
MX4-9-B	20	25	22	22	21	20
MX4-9-C	20	22	18	18	18	17

^aCylinder cracked and bleed water evaporated.

Table E-6. Drainable-water values for grouts prepared from Matrix 5

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX5-1-A	14	16	12	12	12	12
MX5-1-B	10	12	8	11	8	8
MX5-1-C	10	16	9	11	8	8
MX5-2-A	21	26	23	22	22	22
MX5-2-B	22	28	25	26	24	23
MX5-2-C	24	26	22	22	22	22
MX5-3-A	20	22	18	18	18	18
MX5-3-B	20	22	21	19	19	19
MX5-3-C	20	22	18	18	18	18
MX5-4-A	16	17	14	14	13	13
MX5-4-B	19	20	18	18	17	16
MX5-4-C	18	18	15	14	14	14
MX5-5-A	15	18	13	13	13	11
MX5 5-B	14	16	12	12	12	9
MX5-5-C	14	20	16	16	16	14
MX5-6-A	9	10	5	5		4
MX5-6-B	12	12	10	10		8
MX5-6-C	12	12	8	8		5
MX5-7-A	9	8	6	4		4
MX5-7-B	7	8	6	4		4
MX5-7-C	7	8	5	3		3
MX5-8-A	10	16	12	11	10	10
MX5-8-B	8	10	8	7	7	6
MX5-8-C	12	12	10	8	8	7
MX5-9-A	14	22	18	18	17	17
MX5-9-B	11	15	10	8	8	8
MX5-9-C	16	18	16	13	13	13

Table E-7. Drainable-water values for grouts prepared from Matrix 6

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX6-1-A	10	11	8	6	6	5
MX6-1-B	7	6	5	3	3	3
MX6-1-C	6	7	5	2	2	2
MX6-2-A	15	15	14	11	11	11
MX6-2-B	12	12	9	8	8	8
MX6-2-C	12	12	11	8	8	8
MX6-3-A	7	9	4	4	4	4
MX6-3-B	7	9	4	5	4	4
MX6-3-C	8	10	4	54	4	4
MX6-4-A	8	10	5	5	5	4
MX6-4-B	6	7	3	2	2	2
MX6-4-C	7	6	2	2	2	1
MX6-5-A	19	22	19	18	18	16
MX6-5-B	19	21	20	18	18	17
MX6-5-C	14	15	13	11	11	10
MX6-6-A	9	10	7	6	6	6
MX6-6-B	11	13	10	10	9	8
MX6-6-C	12	12	9	7	7	6
MX6-7-A	14	16	12	11	11	11
MX6-7-B	16	18	15	14	14	14
MX6-7-C	14	14	11	10	10	10
MX6-8-A	19	22	20	20	19	18
MX6-8-B	20	13	10	9	9	8
MX6-8-C	12	13	12	10	10	9
MX6-9-A	10	10	7	6	6	6
MX6-9-B	6	*				
MX6-9-C	8	8	6	5	5	3

*Leaking cylinder.

Table E-8. Drainable-water values for grouts prepared from Matrix 7

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX7-1-A	5	6	5	4	4	4
MX7-1-B	6	12	11	10	10	10
MX7-1-C	10	12	11	10	9	9
MX7-2-A	5	4	4	4	3	2
MX7-2-B	5	4	4	4	3	2
MX7-2-C	6	5	4	4	3	2
MX7-3-A	13	13	11	10	10	10
MX7-3-B	10	11	10	9	9	9
MX7-3-C	10	9	9	8	7	7
MX7-4-A	14	22	21	18	18	18
MX7-4-B	14	19	18	16	16	16
MX7-4-C	16	20	19	19	18	17
MX7-5-A	11	11	10	10	9	8
MX7-5-B	8	9	6	6	6	5
MX7-5-C	11	11	10	8	8	8
MX7-6-A	6	6	4	4	4	4
MX7-6-B	6	6	3	4	3	2
MX7-6-C	5	5	2	2	2	2
MX7-7-A	10	11	10	8	8	7
MX7-7-B	11	12	10	10	10	9
MX7-7-C	15	16	15	14	14	14
MX7-8-A	5	4	4	3	3	2
MX7-8-B	5	5	4	3	3	3
MX7-8-C	6	6	4	3	3	2
MX7-9-A	12	9	9	9	9	9
MX7-9-B	10	8	8	8	6	6
MX7-9-C	8	6	6	6	5	5

Table E-9. Drainable-water values for grouts prepared from Matrix 8

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX8-1-A	8	6	4	4	4	4
MX8-1-B	8	8	5	5	5	4
MX8-1-C	9	11	11	11	10	9
MX8-2-A	16	18	17	16	16	15
MX8-2-B	17	19	18	18	17	16
MX8-2-C	16	18	17	16	15	14
MX8-3-A	11	10	10	9	7	7
MX8-3-B	9	10	9	8	7	6
MX8-3-C	6	4	4	4	3 ^a	2
MX8-4-A	16	16	13	13	13	12
MX8-4-B	16	16	15	14	14	14
MX8-4-C	18	17	15	15	15	14
MX8-5-A	19	21	20	20	19	18
MX8-5-B	17	17	15	14	14	14
MX8-5-C	20	20	20	19	17	18
MX8-6-A	18	20	18	17	16	17
MX8-6-B	18	20	18	17	16	16
MX8-6-C	20	20	17	16	16	15
MX8-7-A	18	19	18	18	17	17
MX8-7-B	20	24	22	21	21	20
MX8-7-C	21	23	22	22	21	20
MX8-8-A	14	16	16	14	14	14
MX8-8-B	14	13	13	11	11	11
MX8-8-C	14	14	13	11	11	11
MX8-9-A	6	6	5	4	4	4
MX8-9-B	6	6 ^a	2 ^a	0 ^a	0 ^a	0 ^a
MX8-9-C	7	7	6	6	5	4

^aContainer cracked.

Table E-10. Drainable-water values for grouts prepared from Matrix 9

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX9-1-A	17	19	17	17	15	16
MX9-1-B	16	18	16	16	14	14
MX9-1-C	17	18	16	15	14	15
MX9-2-A	20	23	23	20	19	19
MX9-2-B	20	24	22	23	22	22
MX9-2-C	20	20	18	18	18	18
MX9-3-A	24	24	22	22	22	22
MX9-3-B	27	34	31	31	29	30
MX9-3-C	24	24	21	21	22	22
MX9-4-A	17	20	18	18	17	16
MX9-4-B	12	12	16	9 ^a	9 ^a	9 ^a
MX9-4-C	17	18	18	15	14	15
MX9-5-A	20	22	19	18	18	18
MX9-5-B	19	22	19	18	18	18
MX9-5-C	20	20	18	16	15	16
MX9-6-A	20	21	18	18	18	16
MX9-6-B	22	23	20	20	20	20
MX9-6-C	19	21	20	19	18	17
MX9-7-A	15	16	13	12	12	12
MX9-7-B	12	11	9	8	8	8
MX9-7-C	18	22	19	18 ^a	16 ^a	10 ^a
MX9-8-A	23	26	24	24	23	22
MX9-8-B	25	27	24	23	24	23
MX9-8-C	21	23	20	20	20	20
MX9-9-A	18	19	17	15	16	15
MX9-9-B	15	16	14	12	13	12
MX9-9-C	16	16	12	12	12	11

^aCylinder leaked.

Table E-11. Drainable-water values for grouts prepared from Matrix 10

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX10-1-A	20	24	21	20	20	20
MX10-1-B	20	24	20	20	20	17
MX10-1-C	21	25	22	22	21	21
MX10-2-A	18	20	17	15	14	14
MX10-2-B	18	22	20	19	20	20
MX10-2-C	20	18	16	14	15	14
MX10-3-A	19	18	17	16	14	15
MX10-3-B	19	18	16	16	16	16
MX10-3-C	19	20	16	16	16	16
MX10-4-A	17	20	16	16	15	15
MX10-4-B	18	20	18	17	16	15
MX10-4-C	19	21	17	18	18	16
MX10-5-A	20	23	22	21	20	19
MX10-5-B	22	25	21	21	21	21
MX10-5-C	20	22	18	18	18	18
MX10-6-A	29	30	26	27	26	26
MX10-6-B	30	31	28	28	28	27
MX10-6-C	30	39	37	36	36	36
MX10-7-A	24	26	22	22	22	22
MX10-7-B	26	28	25	25	25	24
MX10-7-C	27	30	26	25	24	24
MX10-8-A	22	23	19	18	18	18
MX10-8-B	22	25	21	22	21	21
MX10-8-C	22	24	19	18	18	18
MX10-9-A	27	30	29	28	28	27
MX10-9-B	28	30	27	28	26	26
MX10-9-C	23	31	30	30	29	29

Table E-12. Drainable-water values for grouts prepared from Matrix 11

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX11-1-A	22	24	23	22	20	20
MX11-1-B	21	23	23	22	20	20
MX11-1-C	20	25	24	24	22	22
MX11-2-A	16	17	15	14	14	14
MX11-2-B	18	22	19	18	18	18
MX11-2-C	20	22	20	20	18	18
MX11-3-A	19	20	19	18	18	17
MX11-3-B	17	17	15	14	14	14
MX11-3-C	20	21	19	18	16	16
MX11-4-A	20	23	20	20	19	18
MX11-4-B	19	21	19	18	18	18
MX11-4-C	19	22	21	20	20	18
MX11-5-A	26	29	28	26	26	25
MX11-5-B	28	30	29	28	27	26
MX11-5-C	24	24	23	23	23	22
MX11-6-A	20	25	24	24	23	22
MX11-6-B	22	24	22	22	22	21
MX11-6-C	26	28	26	26	26	26
MX11-7-A	18	20	17	16	16	16
MX11-7-B	19	19	17	16	16	16
MX11-7-C	18	21	19	18	18	18
MX11-8-A	22	24	22	21	21	21
MX11-8-B	23	24	23	23	21	21
MX11-8-C	21	22	20	19	18	18
MX11-9-A	23	27	26	25	24	24
MX11-9-B	24	28	26	27	26	26
MX11-9-C	31	33	31	30	30	29

Table E-13. Drainable-water values for grouts prepared from Matrix 12

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX12-1-A	12	12	10	9	9	9
MX12-1-B	12	14	11	11	11	11
MX12-1-C	13	14	11	10	10	10
MX12-2-A	16	18	14	14	14	14
MX12-2-B	16	18	14	14	14	14
MX12-2-C	17	16	12	12	12	12
MX12-3-A	16	17	15	15	15	15
MX12-3-B	16	17	14	14	14	14
MX12-3-C	17	22	19	19	19	19
MX12-4-A	14	14	10	10	10	10
MX12-4-B	14	14	9	9	9	9
MX12-4-C	14	14	11	11	11	11
MX12-5-A	10	12	8	8	8	8
MX12-5-B	14	14	8	10	9	9
MX12-5-C	12	13	8	8	8	7
MX12-6-A	10	13	9	9	9	9
MX12-6-B	12	8	6	6	6	6
MX12-6-C	14	14	12	12	12	12
MX12-7-A	12	11	8	8	8	8
MX12-7-B	14	17	15	15	14	14
MX12-7-C	16	16	14	14	14	14
MX12-8-A	14	17	14	14	14	14
MX12-8-B	11	11	8	8	8	8
MX12-8-C	14	16	13	13	12	12
MX12-9-A	15	16	12	12	12	12
MX12-9-B	12	12	10	10	9	9
MX12-9-C	16	16	14	14	13	13

Table E-14. Drainable-water values for grouts prepared from Matrix 13

Run No.	Drainable water (mL) observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX13-1-A	22	24	20	20	20	20
MX13-1-B	20	22	17	16	16	16
MX13-1-C	18	18	15	15	15	15
MX13-2-A	28	30	27	26	26	26
MX13-2-B	26	28	25	24	24	24
MX13-2-C	28	31	31	31	31	31
MX13-3-A	20	24	19	18	18	18
MX13-3-B	20	20	16	16	16	16
MX13-3-C	22	23	18	18	18	18
MX13-4-A	16	19	16	16	15	15
MX13-4-B	18	20	18	17	17	17
MX13-4-C	18	19	16	16	15	15
MX13-5-A	27	36	31	31	31	31
MX13-5-B	24	32	25	25	25	25
MX13-5-C	32	32	29	29	28	28
MX13-6-A	18	20	16	16	16	16
MX13-6-B	18	20	16	16	16	16
MX13-6-C	20	22	16	16	16	16
MX13-7-A	22	26	22	22	22	21
MX13-7-B	23	26	22	21	21	21
MX13-7-C	24	25	20	20	20	20
MX13-8-A	25	27	23	23	23	22
MX13-8-B	27	29	20	20	20	20
MX13-8-C	25	26	25	25	25	25
MX13-9-A	18	20	16	16	16	16
MX13-9-B	18	21	18	18	18	18
MX13-9-C	20	21	16	16	16	16

**Appendix F. UNCONFINED-COMPRESSIVE-STRENGTH DATA FOR ALL
EXPERIMENTAL RUNS**

Table F-1. Unconfined compressive-strength values for grouts prepared from Matrix 1

Run No.	Unconfined compressive strength (psi)			Average ^a
MX1-1-A	465	401	423	430 ± 33
MX1-1-B	369	410	357	379 ± 28
MX1-1-C	439	392	382	404 ± 31
MX1-2-A	474	422	450	449 ± 26
MX1-2-B	516	524	505	515 ± 10
MX1-2-C	410	437	519	455 ± 57
MX1-3-A	416	441	385	414 ± 28
MX1-3-B	392	442	417	417 ± 25
MX1-3-C	364	434	447	415 ± 45
MX1-4-A	460	523	522	501 ± 36
MX1-4-B	476	446	456	493 ± 47
MX1-4-C	527	551	551	543 ± 14
MX1-5-A	354	397	403	385 ± 27
MX1-5-B	418	304	306	343 ± 66
MX1-5-C	467	445	494	468 ± 25
MX1-6-A	627	621	533	594 ± 53
MX1-6-B	468	516	425	470 ± 45
MX1-6-C	395	415	344	384 ± 37
MX1-7-A	271	^b	428	350
MX1-7-B	378	382	357	372 ± 13
MX1-7-C	358	439	^b	398
MX1-8-A	396	509	496	467 ± 62
MX1-8-B	474	512	456	481 ± 29
MX1-8-C	471	438	369	426 ± 52
MX1-9-A	308	307	365	327 ± 33
MX1-9-B	335	331	343	336 ± 6
MX1-9-C	339	356	318	338 ± 19

^aAverage value and one standard deviation.^bSample cracked.

Table F-2. Unconfined compressive-strength values for grouts prepared from Matrix 2

Run No.	Unconfined compressive strength (psi)			Average ^a
MX2-1-A	442	430	463 ^b	445 ± 17
MX2-1-B	393	457		425
MX2-1-C	462	402	464	443 ± 35
MX2-2-A	443	386	452	427 ± 36
MX2-2-B	393	354	378	375 ± 20
MX2-2-C	367	397	396	387 ± 17
MX2-3-A	348	377	403	376 ± 27
MX2-3-B	384	335	334	351 ± 29
MX2-3-C	294	313	341	316 ± 24
MX2-4-A	353	345	331	343 ± 11
MX2-4-B	375	338	311	341 ± 32
MX2-4-C	315	314	316	315 ± 1
MX2-5-A	368	355	355	359 ± 8
MX2-5-B	321	333	316	323 ± 9
MX2-5-C	364	331	369	355 ± 20
MX2-6-A	391	349	386	375 ± 23
MX2-6-B	335	341	334	337 ± 4
MX2-6-C	346	419	425	397 ± 44
MX2-7-A	340	386	373	367 ± 24
MX2-7-B	405	397	416	406 ± 9
MX2-7-C	392	384	365	380 ± 14
MX2-8-A	375	378	316	356 ± 35
MX2-8-B	315	298	328	313 ± 15
MX2-8-C	305	315	304	308 ± 6
MX2-9-A	186 ^c	402	240 ^c	402
MX2-9-B	419	379	390	396 ± 21
MX2-9-C	414	395	383	397 ± 16

^aAverage value and one standard deviation.^bSample cracked.^cCube faces not parallel.

Table F-3. Unconfined compressive-strength values for grouts prepared from Matrix 2R

Run No.	Unconfined compressive strength (psi)			Average ^a
MX2R-1-A	314	388	418	373 ± 53
MX2R-1-B	329	373	401	368 ± 36
MX2R-1-C	409	430	455	431 ± 23
MX2R-2-A	330	421	433	394 ± 56
MX2R-2-B	308	374	431	371 ± 61
MX2R-2-C	298	313	388	333 ± 48
MX2R-3-A	361	335	457	384 ± 64
MX2R-3-B	315	363	400	359 ± 42
MX2R-3-C	306	371	427	366 ± 61
MX2R-4-A	392	402	430	408 ± 19
MX2R-4-B	421	404	368	398 ± 27
MX2R-4-C	320	363	339	341 ± 21
MX2R-5-A	386	328	390	368 ± 34
MX2R-5-B	392	347	396	378 ± 27
MX2R-5-C	419	352	399	390 ± 34
MX2R-6-A	366	391	387	381 ± 14
MX2R-6-B	378	351	472	400 ± 64
MX2R-6-C	359	325	318	334 ± 22
MX2R-7-A	305	334	297	312 ± 20
MX2R-7-B	325	357	382	355 ± 28
MX2R-7-C	314	325	323	321 ± 6
MX2R-8-A	282	287	283	284 ± 3
MX2R-8-B	278	275	266	273 ± 6
MX2R-8-C	278	321	319	306 ± 25
MX2R-9-A	380	345	355	360 ± 18
MX2R-9-B	368	338	381	362 ± 22
MX2R-9-C	377	350	395	374 ± 23

^aAverage value and one standard deviation.

Table F-4. Unconfined compressive-strength values for grouts prepared from Matrix 3

Run No.	Unconfined compressive strength (psi)			Average ^a
	407			
MX3-1-A	334	423	420	417 ± 9
MX3-1-B	306	255	327	305 ± 44
MX3-1-C		271	330	302 ± 29
MX3-2-A	291	362	330	328 ± 36
MX3-2-B	298	311	287	299 ± 12
MX3-2-C	258	277	342	292 ± 44
MX3-3-A	367	357	375	366 ± 9
MX3-3-B	231	329	320	293 ± 54
MX3-3-C	376	395	409	394 ± 16
MX3-4-A	342	337	329	336 ± 6
MX3-4-B	285	321	355	320 ± 35
MX3-4-C	327	329	314	323 ± 8
MX3-5-A	439	424	445	436 ± 10
MX3-5-B	448	455	485	463 ± 20
MX3-5-C	472	470	432	458 ± 22
MX3-6-A	446	445	441	444 ± 3
MX3-6-B	427	463	439	443 ± 19
MX3-6-C	454	477	454	462 ± 13
MX3-7-A	361	363	371	365 ± 6
MX3-7-B	365	351	355	357 ± 7
MX3-7-C	353	365	314	344 ± 27
MX3-8-A	305	316	310	311 ± 5
MX3-8-B	316	332	338	329 ± 12
MX3-8-C	367	373	358	366 ± 7
MX3-9-A	422	452	432	435 ± 15
MX3-9-B	427	425	414	422 ± 7
MX3-9-C	422	442	414	426 ± 14

^aAverage value and one standard deviation.

Table F-5. Unconfined compressive-strength values for grouts prepared from Matrix 4

Run No.	Unconfined compressive strength (psi)			Average ^a
MX4-1-A	436	478	557	490 ± 62
MX4-1-B	562	573	554	563 ± 10
MX4-1-C	442	431	397	423 ± 24
MX4-2-A	517	522	502	514 ± 10
MX4-2-B	519	442	512	491 ± 42
MX4-2-C	427	510	551	496 ± 63
MX4-3-A	485	533	575	531 ± 45
MX4-3-B	506	447	411	455 ± 48
MX4-3-C	428	433	386	416 ± 26
MX4-4-A	431	470	434	445 ± 22
MX4-4-B	440	494	506	480 ± 35
MX4-4-C	482	509	454	482 ± 28
MX4-5-A	368	389	357	371 ± 17
MX4-5-B	365	402	418	395 ± 27
MX4-5-C	390	352	383	375 ± 20
MX4-6-A	318	265	292	292 ± 26
MX4-6-B	289	328	351	323 ± 31
MX4-6-C	320	316	270	302 ± 28
MX4-7-A	426	443	443	437 ± 10
MX4-7-B	392	419	414	408 ± 14
MX4-7-C	411	445	446	434 ± 20
MX4-8-A	504	541	534	526 ± 20
MX4-8-B	508	577	559	548 ± 36
MX4-8-C	545	569	550	555 ± 13
MX4-9-A	369	377	314	354 ± 35
MX4-9-B	310	310	284	301 ± 15
MX4-9-C	323	263	258	281 ± 36

^aAverage value and one standard deviation.

Table F-6. Unconfined compressive-strength values for grouts prepared from Matrix 5

Run No.	Unconfined compressive strength (psi)			Average ^a
MX5-1-A	435	477	427	446 ± 27
MX5-1-B	458	523	521	501 ± 37
MX5-1-C	537	542	473	517 ± 39
MX5-2-A	324	411	368	367 ± 44
MX5-2-B	351	361	407	373 ± 30
MX5-2-C	360	367	331	353 ± 19
MX5-3-A	436	411	449	432 ± 20
MX5-3-B	511	510	523	515 ± 7
MX5-3-C	455	446	537	479 ± 50
MX5-4-A	453	526	516	499 ± 40
MX5-4-B	475	510	470	485 ± 22
MX5-4-C	421	505	489	472 ± 45
MX5-5-A	483	509	482	491 ± 15
MX5-5-B	465	426	399	430 ± 33
MX5-5-C	493	406	498	465 ± 52
MX5-6-A	410	410	422	414 ± 7
MX5-6-B	425	503	428	452 ± 44
MX5-6-C	461	435	^b	448
MX5-7-A	500	501	449	483 ± 30
MX5-7-B	533	457	492	494 ± 38
MX5-7-C	492	481	472	481 ± 10
MX5-8-A	353	370	378	367 ± 13
MX5-8-B	394	412	409	405 ± 9
MX5-8-C	347	371	382	367 ± 18
MX5-9-A	256	265	232	251 ± 17
MX5-9-B	249	276	222	249 ± 27
MX5-9-C	260	249	260	256 ± 7

^aAverage value and one standard deviation.^bSample cracked.

Table F-7. Unconfined compressive-strength values for grouts prepared from Matrix 6

Run No.	Unconfined compressive strength (psi)			Average ^a
MX6-1-A	548	518	631	566 ± 59
MX6-1-B	596	626	622	615 ± 16
MX6-1-C	613	643	624	627 ± 15
MX6-2-A	529	538	521	529 ± 9
MX6-2-B	574	611	600	599 ± 19
MX6-2-C	675	743	710	709 ± 34
MX6-3-A	441	490	491	474 ± 29
MX6-3-B	462	499	394	451 ± 53
MX6-3-C	449	427	392	422 ± 29
MX6-4-A	359	405	393	386 ± 24
MX6-4-B	412	395	393	400 ± 11
MX6-4-C	380	436	411	409 ± 28
MX6-5-A	595	534	461	530 ± 67
MX6-5-B	415	354	415	395 ± 35
MX6-5-C	379	468	414	420 ± 45
MX6-6-A	388	519	494	467 ± 69
MX6-6-B	366	377	502	415 ± 76
MX6-6-C	428	474	436	446 ± 25
MX6-7-A	545	494	454	497 ± 46
MX6-7-B	472	468	475	472 ± 3
MX6-7-C	487	495	440	474 ± 30
MX6-8-A	379	317	304	334 ± 40
MX6-8-B	337	390	367	365 ± 26
MX6-8-C	321	319	289	310 ± 18
MX6-9-A	478	562	498	512 ± 44
MX6-9-B	436	460	464	453 ± 15
MX6-9-C	460	493	537	497 ± 39

^aAverage value and one standard deviation.

Table F-8. Unconfined compressive-strength values for grouts prepared from Matrix 7

Run No.	Unconfined compressive strength (psi)			Average ^a
MX7-1-A	384	431	355	390 ± 38
MX7-1-B	434	436	409	426 ± 14
MX7-1-C	438	485	494	472 ± 30
MX7-2-A	463	418	448	443 ± 23
MX7-2-B	457	451	420	443 ± 20
MX7-2-C	416	472	445	445 ± 29
MX7-3-A	355	422	392	390 ± 33
MX7-3-B	362	396	362	373 ± 20
MX7-3-C	415	396	343	385 ± 38
MX7-4-A	249	277	254	260 ± 15
MX7-4-B	230	216	225	223 ± 7
MX7-4-C	234	237	203	224 ± 19
MX7-5-A	398	394	399	397 ± 2
MX7-5-B	375	374	316	355 ± 34
MX7-5-C	357	360	331	349 ± 16
MX7-6-A	437	470	458	455 ± 17
MX7-6-B	485	527	506	506 ± 21
MX7-6-C	418	445	440	434 ± 14
MX7-7-A	237	295	260	264 ± 29
MX7-7-B	264	301	297	287 ± 20
MX7-7-C	296	296	278	290 ± 10
MX7-8-A	449	464	453	455 ± 8
MX7-8-B	456	482	456	465 ± 15
MX7-8-C	454	407	427	429 ± 24
MX7-9-A	378	365	339	361 ± 20
MX7-9-B	336	321	327	328 ± 8
MX7-9-C	340	318	307	322 ± 17

^aAverage value and one standard deviation.

Table F-9. Unconfined compressive-strength values for grouts prepared from Matrix 8

Run No.	Unconfined compressive strength (psi)			Average ^a
MX8-1-A	388	416	441	416 ± 26
MX8-1-B	418	402	535	452 ± 73
MX8-1-C	503	513	441	486 ± 39
MX8-2-A	414	386	406	402 ± 15
MX8-2-B	390	444	486	440 ± 48
MX8-2-C	381	442	437	420 ± 34
MX8-3-A	402	443	378	407 ± 33
MX8-3-B	386	459	394	413 ± 40
MX8-3-C	394	395	380	390 ± 8
MX8-4-A	343	356	354	351 ± 7
MX8-4-B	352	397	416	388 ± 33
MX8-4-C	466	379	467	437 ± 50
MX8-5-A	311	302	291	301 ± 10
MX8-5-B	330	265	321	305 ± 35
MX8-5-C	306	296	255	286 ± 27
MX8-6-A	209	229	206	215 ± 13
MX8-6-B	272	287	246	268 ± 21
MX8-6-C	247	213	198	220 ± 25
MX8-7-A	274	272	273	273 ± 1
MX8-7-B	333	336	351	340 ± 10
MX8-7-C	319	365	313	332 ± 29
MX8-8-A	566	551	515	544 ± 26
MX8-8-B	483	510	482	491 ± 16
MX8-8-C	411	436	446	431 ± 18
MX8-9-A	468	541	^b	504
MX8-9-B	458	487	522	489 ± 32
MX8-9-C	375	453	452	427 ± 45

^aAverage value and one standard deviation.^bSample cracked.

Table F-10. Unconfined compressive-strength values for grouts prepared from Matrix 9

Run No.	Unconfined compressive strength (psi)			Average ^a
MX9-1-A	322	402	367	364 ± 40
MX9-1-B	377	404	417	399 ± 20
MX9-1-C	678	610	694	661 ± 45
MX9-2-A	470	435	436	447 ± 20
MX9-2-B	425	414	422	420 ± 5.6
MX9-2-C	344	388	416	383 ± 36
MX9-3-A	473	447	482	467 ± 18
MX9-3-B	315	282	324	307 ± 22
MX9-3-C	261	373	303	313 ± 57
MX9-4-A	368	397	314	360 ± 42
MX9-4-B	399	445	425	423 ± 23
MX9-4-C	353	404	383	380 ± 26
MX9-5-A	359	347	347	351 ± 7
MX9-5-B	373	342	355	356 ± 16
MX9-5-C	431	341	409	394 ± 47
MX9-6-A	290	421	341	350 ± 66
MX9-6-B	393	413	420	409 ± 14
MX9-6-C	417	428	415	420 ± 7
MX9-7-A	481	483	430	464 ± 30
MX9-7-B	456	428	432	438 ± 15
MX9-7-C	462	422	437	440 ± 20
MX9-8-A	297	299	301	299 ± 2
MX9-8-B	221	273	281	258 ± 33
MX9-8-C	259	222	^b	240
MX9-9-A	390	390	367	383 ± 12
MX9-9-B	379	392	354	375 ± 19
MX9-9-C	326	375	348	350 ± 24

^aAverage value and one standard deviation.^bSample cracked.

Table F-11. Unconfined compressive-strength values for grouts prepared from Matrix 10

Run No.	Unconfined compressive strength (psi)			Average ^a
MX9-1-A	388	421	412	407 ± 17
MX9-1-B	371	287	393	350 ± 56
MX9-1-C	372	454	295	374 ± 80
MX9-2-A	421	439	465	442 ± 22
MX9-2-B	446	441	394	427 ± 28
MX9-2-C	362	320	400	361 ± 40
MX9-3-A	440	413	414	422 ± 15
MX9-3-B	374	416	398	396 ± 21
MX9-3-C	435	409	^b	422
MX9-4-A	441	465	389	432 ± 39
MX9-4-B	500	485	451	478 ± 25
MX9-4-C	402	415	401	406 ± 8
MX9-5-A	357	378	326	354 ± 26
MX9-5-B	322	308	289	306 ± 16
MX9-5-C	334	320	^b	327
MX9-6-A	306	286	296	296 ± 10
MX9-6-B	382	434	455	424 ± 38
MX9-6-C	315	326	377	339 ± 33
MX9-7-A	453	533	451	479 ± 47
MX9-7-B	545	592	489	542 ± 52
MX9-7-C	508	528	497	511 ± 15
MX9-8-A	637	626	669	644 ± 22
MX9-8-B	659	691	675	675 ± 16
MX9-8-C	714	721	671	702 ± 27
MX9-9-A	317	302	354	324 ± 27
MX9-9-B	405	402	399	402 ± 3
MX9-9-C	376	398	390	388 ± 11

^aAverage value and one standard deviation.

^bSample cracked.

Table F-12. Unconfined compressive-strength values for grouts prepared from Matrix 11

Run No.	Unconfined compressive strength (psi)			Average ^a
MX11-1-A	587	651	572	603 ± 42
MX11-1-B	449	484	486	473 ± 21
MX11-1-C	473	461	428	454 ± 24
MX11-2-A	575	632	607	605 ± 29
MX11-2-B	724	646	717	696 ± 43
MX11-2-C	617	708	684	670 ± 47
MX11-3-A	580	564	558	567 ± 11
MX11-3-B	680	685	670	678 ± 8
MX11-3-C	671	627	524	608 ± 76
MX11-4-A	327	423	356	369 ± 50
MX11-4-B	423	424	383	410 ± 23
MX11-4-C	303	366	371	347 ± 37
MX11-5-A	355	349	322	342 ± 17
MX11-5-B	382	390	385	385 ± 4
MX11-5-C	413	391	321	375 ± 48
MX11-6-A	370	373	353	365 ± 11
MX11-6-B	403	476	350	410 ± 63
MX11-6-C	282	472	392	382 ± 95
MX11-7-A	792	859	857	836 ± 38
MX11-7-B	801	830	865	832 ± 32
MX11-7-C	778	820	850	816 ± 36
MX11-8-A	802	802	742	782 ± 35
MX11-8-B	812	857	761	810 ± 48
MX11-8-C	913	897	868	893 ± 23
MX11-9-A	620	582	564	589 ± 28
MX11-9-B	522	622	554	566 ± 51
MX11-9-C	790	721	832	781 ± 56

^aAverage value and one standard deviation.

Table F-13. Unconfined compressive-strength values for grouts prepared from Matrix 12

Run No.	Unconfined compressive strength (psi)			Average ^a
MX12-1-A	529	577	546	550 ± 24
MX12-1-B	580	561	^b	571
MX12-1-C	447	583	606	545 ± 86
MX12-2-A	484	526	493	501 ± 22
MX12-2-B	445	619	507	524 ± 88
MX12-2-C	513	561	506	527 ± 30
MX12-3-A	572	543	514	543 ± 29
MX12-3-B	412	493	479	461 ± 43
MX12-3-C	465	475	497	479 ± 16
MX12-4-A	486	483	490	486 ± 4
MX12-4-B	433	489	454	459 ± 28
MX12-4-C	515	555	513	528 ± 24
MX12-5-A	580	635	568	594 ± 36
MX12-5-B	614	728	635	659 ± 61
MX12-5-C	515	462	632	536 ± 87
MX12-6-A	609	647	544	600 ± 52
MX12-6-B	585	676	550	590 ± 43
MX12-6-C	570	530	568	556 ± 22
MX12-7-A	670	544	^b	607
MX12-7-B	609	603	640	617 ± 20
MX12-7-C	611	533	614	586 ± 46
MX12-8-A	457	389	404	417 ± 36
MX12-8-B	414	448	439	433 ± 18
MX12-8-C	417	428	416	420 ± 7
MX12-9-A	^b	525	477	501
MX12-9-B	493	518	480	497 ± 19
MX12-9-C	481	495	435	470 ± 31

^aAverage value and one standard deviation.^bSample cracked.

Table F-14. Unconfined compressive-strength values for grouts prepared from Matrix 13

Run No.	Unconfined compressive strength (psi)			Average ^a
MX13-1-A	610	559	532	567 ± 40
MX13-1-B	539	484	485	503 ± 32
MX13-1-C	383	367	393	380 ± 13
MX13-2-A	484	464	518	489 ± 27
MX13-2-B	484	592	549	542 ± 55
MX13-2-C	541	511	580	544 ± 35
MX13-3-A	427	392	417	412 ± 18
MX13-3-B	542	499	497	513 ± 25
MX13-3-C	379	438	427	415 ± 31
MX13-4-A	644	686	625	652 ± 31
MX13-4-B	545	523	538	535 ± 11
MX13-4-C	630	689	610	643 ± 41
MX13-5-A	469	522	473	488 ± 30
MX13-5-B	475	486	473	478 ± 7
MX13-5-C	490	476	456	474 ± 17
MX13-6-A	478	506	592	525 ± 59
MX13-6-B	447	536	478	487 ± 45
MX13-6-C	490	470	477	479 ± 10
MX13-7-A	530	529	526	528 ± 2
MX13-7-B	549	511	561	540 ± 26
MX13-7-C	468	448	475	463 ± 14
MX13-8-A	457	445	439	447 ± 10
MX13-8-B	484	447	409	447 ± 37
MX13-8-C	406	423	387	405 ± 18
MX13-9-A	483	443	401	442 ± 41
MX13-9-B	506	438	457	467 ± 35
MX13-9-C	400	384	409	397 ± 13

^aAverage value and one standard deviation.

Appendix G. AVERAGED FLUID-PROPERTY DATA

Table G-1. Summary of properties^a for fluid grout prepared from Matrix 1

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX1-1	14.8 ± 0.1	5.7 ± 0.1	2.1 ± 0.3	5.8 ± 0.8	13.5 ± 0.1
MX1-2	15.5 ± 0.4	5.7 ± 0	3.2 ± 0.3	8.7 ± 0.7	13.5 ± 0
MX1-3	15.4 ± 4	5.5 ± 0	2.5 ± 0.1	6.8 ± 0.3	13.2 ± 0
MX1-4	14.8 ± 0.7	5.6 ± 0	2.5 ± 0.1	6.9 ± 0.1	13.3 ± 0.1
MX1-5	13.1 ± 0.7	5.5 ± 0	1.7 ± 0.2	4.7 ± 0.4	13.2 ± 0
MX1-6	15.3 ± 0.3	5.7 ± 0	2.3 ± 0.2	6.2 ± 0.6	13.5 ± 0
MX1-7	13.3 ± 0.2	5.5 ± 0.1	2.1 ± 0.2	5.8 ± 0.6	13.2 ± 0
MX1-8	14.2 ± 0.8	5.6 ± 0	2.3 ± 0.2	6.2 ± 0.4	13.3 ± 0.1
MX1-9	13.3 ± 0.6	5.6 ± 0	17.7 ± 15	48.5 ± 42	13.3 ± 0
Average ^b	14.6 ± 1.5	5.6 ± 0	2.3 ± 0.4	6.4 ± 1.2	13.3 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data except run MX1-9.

Table G-2. Summary of properties^a for fluid grout prepared from Matrix 2

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX2-1	13.3 ± 0.6	5.7 ± 0	2.3 ± 0.1	6.3 ± 0.3	13.6 ± 0
MX2-2	11.9 ± 0.1	5.6 ± 0	2.0 ± 0.3	5.5 ± 0.9	13.3 ± 0
MX2-3	12.3 ± 0.1	5.6 ± 0	2.6 ± 0.1	7.2 ± 0.3	13.3 ± 0.1
MX2-4	14.3 ± 0.3	5.7 ± 0	4.2 ± 0.2	11.5 ± 0.5	13.6 ± 0
MX2-5	13.9 ± 0.6	5.7 ± 0	3.9 ± 0.9	10.8 ± 2.5	13.5 ± 0
MX2-6	12.8 ± 0.6	5.6 ± 0	1.6 ± 0.2	4.6 ± 0.4	13.3 ± 0.1
MX2-7	14.4 ± 0.4	5.7 ± 0	2.3 ± 0.3	6.2 ± 0.8	13.6 ± 0
MX2-8	13.7 ± 0.3	5.6 ± 0.1	3.7 ± 0.5	10.1 ± 1.2	13.4 ± 0.1
MX2-9	15.8 ± 0.2	5.8 ± 0.1	5.8 ± 0	16.8 ± 2.0	13.7 ± 0
Average ^b	13.6 ± 1.2	5.7 ± 0.1	3.2 ± 1.3	8.9 ± 3.9	13.5 ± 0.2

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-3. Summary of properties^a for fluid grout prepared from Matrix 2R

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX2R-1	14.3 ± 0.2	5.6 ± 0	1.5 ± 0.2	4.2 ± 0.6	13.4 ± 0
MX2R-2	11.9 ± 0.6	5.5 ± 0	1.3 ± 0	3.5 ± 0	13.1 ± 0
MX2R-3	12.2 ± 0.6	5.5 ± 0	1.2 ± 0.1	3.2 ± 0.3	13.0 ± 0.1
MX2R-4	15.0 ± 0.1	5.6 ± 0	1.8 ± 0.2	5.0 ± 0.5	13.4 ± 0
MX2R-5	14.1 ± 0.5	5.6 ± 0.1	1.3 ± 0	3.5 ± 0	13.2 ± 0
MX2R-6	13.2 ± 1.1	5.5 ± 0	1.2 ± 0.1	3.3 ± 0.3	13.0 ± 0
MX2R-7	14.8 ± 0.5	5.6 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.4 ± 0
MX2R-8	13.0 ± 0.5	5.5 ± 0	1.3 ± 0.2	3.5 ± 0.5	13.1 ± 0
MX2R-9	14.3 ± 0.1	5.6 ± 0	1.6 ± 0.1	4.3 ± 0.3	13.4 ± 0
Average ^b	13.6 ± 1.2	5.6 ± 0.1	1.4 ± 0.2	3.9 ± 0.7	13.2 ± 0.2

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table G-4. Summary of properties^a for fluid grout prepared from Matrix 3

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX3-1	15.2 ± 0.3	5.7 ± 0	5.4 ± 0.3	14.8 ± 0.8	13.6 ± 0.06
MX3-2	14.1 ± 0.4	5.6 ± 0	4.7 ± 0.4	13.0 ± 1.0	13.4 ± 0
MX3-3	15.0 ± 0.3	5.7 ± 0	6.9 ± 1.6	18.8 ± 4.3	13.6 ± 0
MX3-4	13.5 ± 0.5	5.6 ± 0	4.6 ± 0.9	12.5 ± 2.3	13.3 ± 0
MX3-5	16.0 ± 0.3	5.7 ± 0	5.0 ± 0.5	13.8 ± 1.4	13.5 ± 0
MX3-6	17.0 ± 0.3	5.7 ± 0	8.7 ± 0.5	23.8 ± 1.3	13.7 ± 0.06
MX3-7	14.5 ± 0.6	5.6 ± 0	5.1 ± 0.3	14.0 ± 0.9	13.3 ± 0.06
MX3-8	14.6 ± 0.4	5.6 ± 0	6.8 ± 1.2	18.5 ± 3.3	13.4 ± 0
MX3-9	14.8 ± 0.6	5.7 ± 0	3.3 ± 0.8	9.0 ± 2.2	13.5 ± 0
Average ^b	15.0 ± 1.0	5.7 ± 0.05	5.6 ± 1.7	15.4 ± 4.6	13.5 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table G-5. Summary of properties^a for fluid grout prepared from Matrix 4

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX4-1	14.7 ± 0.2	5.6 ± 0	2.3 ± 0.2	6.3 ± 0.6	13.4 ± 0.06
MX4-2	16.2 ± 0.3	5.7 ± 0	2.3 ± 0.3	6.3 ± 0.8	13.6 ± 0.06
MX4-3	16.2 ± 0.2	5.7 ± 0	2.2 ± 0.3	6.0 ± 0.9	13.6 ± 0
MX4-4	16.6 ± 0.2	5.7 ± 0.06	2.3 ± 0.3	6.3 ± 0.8	13.5 ± 0.06
MX4-5	14.3 ± 0.3	5.6 ± 0	1.6 ± 0	4.5 ± 0	13.3 ± 0
MX4-6	13.1 ± 0.5	5.6 ± 0.06	1.5 ± 0.2	4.0 ± 0.5	13.2 ± 0.06
MX4-7	14.0 ± 0.4	5.6 ± 0	1.6 ± 0	4.5 ± 0	13.3 ± 0.06
MX4-8	15.4 ± 0.3	5.7 ± 0	2.3 ± 0.3	6.2 ± 0.8	13.5 ± 0
MX4-9	14.1 ± 0.06	5.6 ± 0	2.1 ± 0.5	5.7 ± 1.4	13.3 ± 0.06
Average ^b	15.0 ± 1.2	5.6 ± 0.06	2.0 ± 0.4	5.5 ± 1.1	13.4 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-6. Summary of properties^a for fluid grout prepared from Matrix 5

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb/100 ft ³)	Density (lb/gal)
MX5-1	16.8 ± 0.06	5.6 ± 0	2.1 ± 0.3	5.7 ± 0.8	13.4 ± 0
MX5-2	14.5 ± 0.4	5.5 ± 0	1.6 ± 0.06	4.3 ± 0.3	13.1 ± 0
MX5-3	14.6 ± 0.3	5.5 ± 0	1.7 ± 0.1	4.8 ± 0.3	13.1 ± 0
MX5-4	18.9 ± 0.9	5.5 ± 0	1.6 ± 0.4	4.5 ± 1.0	13.2 ± 0.06
MX5-5	16.1 ± 0.4	5.6 ± 0	2.1 ± 0.1	5.7 ± 0.3	13.4 ± 0
MX5-6	16.7 ± 0.3	5.6 ± 0	2.3 ± 0.2	6.2 ± 0.6	13.4 ± 0
MX5-7	17.8 ± 0.4	5.6 ± 0	2.5 ± 0.1	6.8 ± 0.3	13.4 ± 0.06
MX5-8	16.2 ± 0.2	5.6 ± 0	2.4 ± 0.2	6.5 ± 0.5	13.4 ± 0
MX5-9	15.1 ± 0.3	5.6 ± 0	1.7 ± 0.1	4.8 ± 0.3	13.3 ± 0
Average ^b	16.0 ± 1.1	5.6 ± 0.05	2.0 ± 0.4	5.5 ± 1.0	13.3 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-7. Summary of properties^a for fluid grout prepared from Matrix 6

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _p /100 ft ²)	Density (lb/gal)
MX6-1	17.9 ± 0.5	5.6 ± 0	2.8 ± 0.3	7.7 ± 0.7	13.4 ± 0
MX6-2	15.9 ± 0.8	5.5 ± 0	2.0 ± 0.4	5.5 ± 1.0	13.1 ± 0
MX6-3	18.5 ± 0.8	5.6 ± 0	2.1 ± 0.3	5.7 ± 0.8	13.4 ± 0
MX6-4	17.9 ± 1.0	5.6 ± 0	2.4 ± 0.2	6.5 ± 0.5	13.3 ± 0
MX6-5	14.8 ± 0.4	5.5 ± 0	1.7 ± 0.3	4.5 ± 0.9	13.0 ± 0
MX6-6	14.5 ± 0.2	5.5 ± 0	1.9 ± 0.3	5.3 ± 0.8	13.1 ± 0
MX6-7	16.1 ± 0.1	5.6 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.2 ± 0.06
MX6-8	15.1 ± 0.3	5.5 ± 0	1.5 ± 0.2	4.0 ± 0.5	13.2 ± 0
MX6-9	16.5 ± 1.0	5.6 ± 0	2.4 ± 0	6.5 ± 0	13.4 ± 0
Average ^b	16.3 ± 1.5	5.6 ± 0.05	2.0 ± 0.5	5.6 ± 1.3	13.2 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-8. Summary of properties^a for fluid grout prepared from Matrix 7

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX7-1	18.2 ± 1.0	5.7 ± 0.1	2.5 ± 0.1	6.8 ± 0.3	13.5 ± 0
MX7-2	18.0 ± 0.3	5.6 ± 0	2.6 ± 0.3	7.2 ± 0.8	13.5 ± 0
MX7-3	18.2 ± 0.3	5.6 ± 0	2.0 ± 0.2	5.5 ± 0.5	13.4 ± 0.1
MX7-4	15.4 ± 0.6	5.5 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.2 ± 0.1
MX7-5	16.4 ± 0.1	5.5 ± 0	2.0 ± 0.2	5.5 ± 0.5	13.2 ± 0
MX7-6	18.3 ± 0.9	5.6 ± 0.1	2.4 ± 0	6.5 ± 0	13.5 ± 0
MX7-7	16.3 ± 0.2	5.6 ± 0	1.7 ± 0.1	4.8 ± 0.3	13.3 ± 0.1
MX7-8	17.8 ± 0.5	5.7 ± 0	2.5 ± 0.1	6.8 ± 0.3	13.3 ± 0
MX7-9	15.2 ± 0.7	5.6 ± 0	2.0 ± 0.2	5.5 ± 0.5	13.3 ± 0
Average ^b	17.1 ± 1.3	5.6 ± 0.1	2.2 ± 0.4	5.9 ± 1.0	13.4 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-9. Summary of properties^a for fluid grout prepared from Matrix 8

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX8-1	16.7 ± 0.4	5.6 ± 0	2.3 ± 0.1	6.3 ± 0.3	13.4 ± 0
MX8-2	16.0 ± 1.2	5.5 ± 0	1.7 ± 0.1	4.8 ± 0.3	13.1 ± 0.1
MX8-3	17.3 ± 0.4	5.6 ± 0	1.8 ± 0	5.0 ± 0	13.4 ± 0
MX8-4	16.6 ± 0.5	5.6 ± 0	1.6 ± 0.1	4.3 ± 0.3	13.3 ± 0
MX8-5	15.7 ± 0.5	5.5 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.2 ± 0
MX8-6	14.8 ± 0.2	5.5 ± 0	1.4 ± 0.2	3.7 ± 0.6	13.1 ± 0
MX8-7	16.1 ± 0.3	5.5 ± 0	1.8 ± 0	5.0 ± 0	13.2 ± 0
MX8-8	17.1 ± 0.8	5.6 ± 0	1.9 ± 1.1	6.8 ± 0.3	13.5 ± 0.1
MX8-9	17.5 ± 0.4	5.7 ± 0	4.6 ± 3.9	12.7 ± 10.7	13.5 ± 0
Average ^b	16.4 ± 0.9	5.6 ± 0.1	2.2 ± 1.4	5.9 ± 3.9	13.3 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-10. Summary of properties^a for fluid grout prepared from Matrix 9

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX9-1	16.8 ± 0.4	5.6 ± 0	1.5 ± 0.3	4.2 ± 0.8	13.4 ± 0
MX9-2	14.9 ± 0.1	5.5 ± 0	1.6 ± 0.1	4.3 ± 0.3	13.1 ± 0
MX9-3	14.3 ± 0.5	5.5 ± 0	1.2 ± 0.1	3.2 ± 0.3	13.1 ± 0
MX9-4	16.1 ± 0.5	5.6 ± 0	1.9 ± 0.1	5.2 ± 0.3	13.5 ± 0
MX9-5	14.8 ± 0.5	5.6 ± 0	1.5 ± 0.1	4.2 ± 0.3	13.3 ± 0
MX9-6	15.2 ± 0.6	5.5 ± 0	1.6 ± 0.1	4.3 ± 0.3	13.1 ± 0.1
MX9-7	16.3 ± 1.0	5.6 ± 0	2.1 ± 0.1	5.7 ± 0.3	13.5 ± 0.1
MX9-8	15.4 ± 0.2	5.5 ± 0.1	1.6 ± 0.2	4.3 ± 0.6	13.2 ± 0
MX9-9	17.7 ± 0.3	5.6 ± 0	2.1 ± 0.3	5.8 ± 0.8	13.4 ± 0
Average ^b	15.7 ± 1.1	5.6 ± 0.1	1.7 ± 0.3	4.6 ± 0.9	13.3 ± 0.2

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table G-11. Summary of properties^a for fluid grout prepared from Matrix 10

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX10-1	15.2 ± 0.8	5.5 ± 0	1.3 ± 0.2	3.5 ± 0.5	13.2 ± 0.1
MX10-2	17.0 ± 0.3	5.6 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.3 ± 0
MX10-3	16.3 ± 0.5	5.6 ± 0	1.6 ± 0.1	4.3 ± 0.3	13.3 ± 0
MX10-4	16.5 ± 0.3	5.6 ± 0	1.5 ± 0.2	4.0 ± 0.5	13.3 ± 0
MX10-5	14.7 ± 0.4	5.5 ± 0	1.4 ± 0.1	3.7 ± 0.3	13.1 ± 0
MX10-6	14.1 ± 0.5	5.5 ± 0	1.3 ± 0	3.5 ± 0	13.0 ± 0.1
MX10-7	14.6 ± 0.4	5.5 ± 0	1.4 ± 0.1	3.7 ± 0.3	13.1 ± 0
MX10-8	15.5 ± 0.5	5.6 ± 0	1.5 ± 0.1	4.2 ± 0.3	13.3 ± 0
MX10-9	14.7 ± 0.3	5.5 ± 0	1.3 ± 0	3.5 ± 0	13.1 ± 0
Average ^b	15.4 ± 1.0	5.5 ± 0.1	1.4 ± 0.2	3.9 ± 0.5	13.2 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-12. Summary of properties^a for fluid grout prepared from Matrix 11

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX11-1	15.1 ± 0.4	5.5 ± 0	1.5 ± 0.1	4.2 ± 0.3	13.2 ± 0
MX11-2	15.5 ± 0.4	5.6 ± 0	2.0 ± 0.2	5.5 ± 0.5	13.4 ± 0
MX11-3	15.3 ± 0.4	5.6 ± 0	1.7 ± 0.2	4.8 ± 0.6	13.4 ± 0
MX11-4	16.1 ± 0.6	5.6 ± 0	1.7 ± 0.2	4.7 ± 0.6	13.4 ± 0.1
MX11-5	14.3 ± 0.9	5.5 ± 0	1.3 ± 0	3.5 ± 0	13.0 ± 0
MX11-6	14.1 ± 0.4	5.5 ± 0	1.3 ± 0.2	3.5 ± 0.5	13.0 ± 0
MX11-7	15.7 ± 0.1	5.6 ± 0	1.6 ± 0.2	4.5 ± 0.5	13.3 ± 0
MX11-8	14.4 ± 0.6	5.5 ± 0	1.4 ± 0.1	3.8 ± 0.3	13.1 ± 0
MX11-9	14.8 ± 0.2	5.5 ± 0	1.4 ± 0.1	3.8 ± 0.3	13.1 ± 0
Average ^b	15.0 ± 0.8	5.5 ± 0.1	1.6 ± 0.3	4.1 ± 1.0	13.2 ± 0.2

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-13. Summary of properties^a for fluid grout prepared from Matrix 12

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX12-1	15.9 ± 0.6	5.6 ± 0	2.9 ± 0.2	8.0 ± 0.5	13.3 ± 0
MX12-2	14.4 ± 0.5	5.5 ± 0	1.9 ± 0.2	5.2 ± 0.6	13.0 ± 0
MX12-3	14.0 ± 0.7	5.4 ± 0	1.7 ± 0.1	4.8 ± 0.3	12.9 ± 0.1
MX12-4	15.7 ± 0.2	5.5 ± 0	2.1 ± 0.1	5.8 ± 0.3	13.1 ± 0
MX12-5	16.2 ± 0.2	5.5 ± 0	2.9 ± 0.3	7.8 ± 0.8	13.2 ± 0
MX12-6	17.5 ± 0.4	5.6 ± 0	3.4 ± 0.3	9.5 ± 0.9	13.3 ± 0
MX12-7	16.6 ± 0.2	5.6 ± 0	3.3 ± 0.2	9.0 ± 0.5	13.3 ± 0
MX12-8	15.3 ± 0.2	5.5 ± 0	2.3 ± 0.1	6.3 ± 0.3	13.1 ± 0
MX12-9	15.8 ± 0.3	5.5 ± 0	2.4 ± 0.2	6.5 ± 0.5	13.0 ± 0.1
Average ^b	15.7 ± 1.1	5.5 ± 0.1	2.6 ± 0.6	7.0 ± 1.7	13.1 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table G-14. Summary of properties^a for fluid grout prepared from Matrix 13

Run No.	Critical velocity (gal/min)	Frictional pressure drop (psi/100 ft)	Pump-head pressure (psi)	10-min gel strength (lb _f /100 ft ²)	Density (lb/gal)
MX13-1	15.2 ± 0.3	5.6 ± 0	2.1 ± 0.2	5.8 ± 0.6	13.3 ± 0
MX13-2	13.9 ± 0.6	5.5 ± 0	1.5 ± 0.1	4.2 ± 0.3	13.0 ± 0
MX13-3	16.7 ± 0.2	5.6 ± 0	2.3 ± 0.3	6.2 ± 0.8	13.3 ± 0.1
MX13-4	16.3 ± 0.6	5.6 ± 0	2.5 ± 0.1	6.7 ± 0.3	13.3 ± 0
MX13-5	14.1 ± 0.5	5.5 ± 0	1.6 ± 0	4.5 ± 0	13.1 ± 0.1
MX13-6	15.2 ± 0.2	5.6 ± 0	1.7 ± 0.1	4.7 ± 0.3	13.4 ± 0
MX13-7	13.9 ± 0.8	5.5 ± 0	1.4 ± 0.1	3.8 ± 0.3	13.1 ± 0.1
MX13-8	14.4 ± 0.2	5.5 ± 0	1.5 ± 0.1	4.2 ± 0.3	13.1 ± 0
MX13-9	14.8 ± 0.2	5.5 ± 0.1	1.7 ± 0.1	4.7 ± 0.3	13.2 ± 0
Average ^b	14.9 ± 1.0	5.5 ± 0.1	1.8 ± 0.4	5.0 ± 1.0	13.2 ± 0.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Appendix H. AVERAGED DRAINABLE-WATER DATA

Table H-1. Summary of drainable-water data for grouts prepared from Matrix 1

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX1-1	5.3 ± 1.3	6.1 ± 1.7	4.86 ± 1.4	4.5 ± 1.7	4.5 ± 1.7	4.4 ± 1.4
MX1-2	3.7 ± 1.0	4.3 ± 1.2	2.8 ± 1.4	3.1 ± 0.8	2.7 ± 1.2	2.5 ± 1.4
MX1-3	5.5 ± 0.2	5.6 ± 0.4	5.1 ± 0.6	4.0 ± 0	4.0 ± 0	3.3 ± 0.6
MX1-4	4.4 ± 0.4	4.1 ± 0.6	3.5 ± 1.2	2.7 ± 0.5	2.4 ± 0.4	2.4 ± 0.7
MX1-5	7.1 ± 0.2	7.1 ± 0.2	6.5 ± 0.6	5.9 ± 0.5	5.6 ± 0	5.7 ± 0.2
MX1-6	4.3 ± 0.5	4.1 ± 0.6	4.0 ± 0.7	3.2 ± 0.8	2.5 ± 0.6	2.4 ± 0.7
MX1-7	6.9 ± 1.6	7.1 ± 1.4	6.0 ± 1.1	5.3 ± 1.4	5.3 ± 1.2	5.5 ± 1.4
MX1-8	4.4 ± 0.4	4.1 ± 0.5	3.9 ± 0.5	3.3 ± 0.2	2.9 ± 0.5	2.8 ± 0.8
MX1-9	9.5 ± 1.2	21.7 ± 0.6	21.1 ± 0.5	20.9 ± 0.6	21.1 ± 0.5	21.1 ± 0.5
Average ^b	5.2 ± 1.4	5.3 ± 1.5	4.6 ± 1.5	4.0 ± 1.3	3.8 ± 1.5	3.6 ± 1.6

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data except run MX1-9.

Table H-2 . Summary of drainable-water data for grouts prepared from Matrix 2

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX2-1	8.4 ± 1.5	9.5 ± 2.7	8.3 ± 2.9	8.1 ± 3.1	7.7 ± 2.4	7.9 ± 2.7
MX2-2	13.3 ± 1.8	19.6 ± 0.8	18.5 ± 1.0	18.5 ± 0.5	18.3 ± 0.6	18.1 ± 0.5
MX2-3	14.0 ± 0.4	20.4 ± 0.7	19.2 ± 0.8	18.9 ± 0.5	18.5 ± 0.6	18.1 ± 0.5
MX2-4	11.5 ± 1.7	14.3 ± 2.7	13.5 ± 2.3	12.7 ± 2.3	12.8 ± 2.4	12.8 ± 2.4
MX2-5	11.1 ± 0.8	16.9 ± 0.8	14.9 ± 0.9	15.5 ± 1.0	15.5 ± 0.9	15.3 ± 1.2
MX2-6	12.7 ± 1.2	13.3 ± 2.0	11.9 ± 1.9	11.6 ± 1.8	11.3 ± 1.6	11.6 ± 1.7
MX2-7	8.8 ± 0.4	9.1 ± 1.7	7.7 ± 1.2	7.5 ± 0.9	7.2 ± 1.1	7.3 ± 0.8
MX2-8	11.3 ± 0.2	16.8 ± 0.4	15.3 ± 1.3	15.2 ± 1.4	15.2 ± 1.4	15.1 ± 1.5
MX2-9	9.5 ± 1.0	14.4 ± 3.2	12.8 ± 3.7	12.0 ± 3.2	12.3 ± 3.6	12.1 ± 3.4
Average ^b	11.2 ± 2.1	14.9 ± 4.1	13.6 ± 4.2	13.4 ± 9.2	13.2 ± 4.2	13.2 ± 4.1

^aAverage values and one standard deviation obtained from three replicates.^bAverage value and one standard deviation obtained from all data.

Table H-3. Summary of drainable-water data for grouts prepared from Matrix 2R

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX2R-1	3.9 ± 0.2	3.6 ^b	3.6 ^b	3.2 ^b	2.6 ^b	2.0 ^c
MX2R-2	11.2 ± 0.8	12.5 ± 1.2	12.4 ± 1.2	12.0 ± 1.2	12.0 ± 1.2	11.7 ± 1.2
MX2R-3	12.3 ± 0.5	14.0 ± 0.7	13.9 ± 0.9	13.9 ± 0.9	13.9 ± 0.9	14.0 ± 1.1
MX2R-4	7.1 ± 0.2	8.0 ± 1.1	6.9 ± 0.5	6.9 ± 0.5	6.8 ± 0.7	6.8 ± 0.7
MX2R-5	9.2 ± 0.7	9.9 ± 0.9	9.2 ± 0.4	8.9 ± 0.2	8.8 ± 0.4	8.4 ± 0
MX2R-6	12.4 ± 0.4	12.8 ± 0	12.1 ± 0.5	11.9 ± 0.2	11.9 ± 0.2	11.5 ± 0.6
MX2R-7	8.1 ± 0.6	7.9 ± 0.8	7.5 ± 0.5	6.5 ± 0.6	6.5 ± 0.6	6.4 ± 0.8
MX2R-8	9.5 ± 0.2	10.8 ± 0.7	9.5 ± 1.5	8.9 ± 1.3	8.9 ± 1.3	8.8 ± 1.4
MX2R-9	7.5 ± 0.2	6.9 ± 0.5	6.1 ± 0.5	5.6 ± 0.8	5.5 ± 0.6	5.3 ± 0.6
Average ^d	9.0 ± 2.3	9.8 ± 3.1	9.2 ± 3.2	8.9 ± 3.3	8.8 ± 3.4	9.1 ± 3.0

^aAverage values and one standard deviation obtained from three replicates.^bAverage value obtained from two replicates.^cSingle data point.^dAverage values and one standard deviation obtained from all data.

Table H-4. Summary of drainable-water data for grouts prepared from Matrix 3

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX3-1	7.2 ± 2.2	9.7 ± 2.8	7.6 ± 2.9	7.6 ± 3.0	7.5 ± 2.7	7.3 ± 2.7
MX3-2	9.7 ± 2.6	11.2 ± 2.9	10.0 ± 3.3	9.5 ± 3.5	9.3 ± 3.2	8.8 ± 3.3
MX3-3	6.5 ± 3.0	6.5 ± 2.3	5.5 ± 2.7	5.5 ± 2.3	5.2 ± 2.5	5.1 ± 2.6
MX3-4	12.0 ± 0.4	13.9 ± 1.0	12.8 ± 0.7	12.7 ± 1.3	12.5 ± 1.2	12.5 ± 0.8
MX3-5	8.9 ± 1.6	9.5 ± 2.0	8.8 ± 2.0	8.4 ± 2.0	8.3 ± 2.0	8.3 ± 2.0
MX3-6	6.3 ± 2.2	9.1 ± 1.0	8.3 ± 1.0	8.3 ± 1.2	8.1 ± 1.3	8.3 ± 1.2
MX3-7	8.9 ± 3.0	18.1 ± 1.5	15.9 ± 1.9	16.0 ± 1.8	15.9 ± 1.9	15.9 ± 1.9
MX3-8	9.7 ± 0.8	12.8 ± 1.4	11.9 ± 1.0	11.6 ± 1.2	11.9 ± 1.4	11.6 ± 1.2
MX3-9	8.1 ± 1.5	9.2 ± 1.7	8.1 ± 1.9	7.7 ± 1.9	7.7 ± 1.9	7.7 ± 1.9
Average ^b	8.6 ± 2.5	11.1 ± 3.7	9.9 ± 3.5	9.7 ± 3.6	9.6 ± 3.6	9.5 ± 3.6

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table H-5. Summary of drainable-water data for grouts prepared from Matrix 4

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX4-1	8.4 ± 2.4	8.9 ± 2.9	7.9 ± 3.0	7.9 ± 3.0	7.9 ± 3.0	7.9 ± 3.0
MX4-2	4.7 ± 0.8	4.9 ± 1.0	3.6 ± 1.1	3.3 ± 1.0	2.9 ± 1.0	2.8 ± 1.1
MX4-3	5.6 ± 0.7	5.3 ± 1.2	4.1 ± 1.6	4.0 ± 1.8	3.2 ± 2.1 ^b	2.9 ± 2.6 ^b
MX4-4	4.8 ± 0.8	4.5 ± 0.9	3.1 ± 0.8	2.9 ± 0.9	2.8 ± 1.1	2.1 ± 0.9
MX4-5	6.9 ± 1.2	7.9 ± 1.3	7.1 ± 1.6	6.4 ± 1.4	6.4 ± 1.4	6.4 ± 1.4
MX4-6	10.4 ± 0.4	12.3 ± 0.5	11.7 ± 0.9	11.5 ± 0.5	11.3 ± 0.6	11.1 ± 0.8
MX4-7	8.0 ± 0.7	8.9 ± 0.5	7.3 ± 0.5	6.9 ± 0.5	6.9 ± 0.5	6.9 ± 0.5
MX4-8	4.5 ± 1.2	4.7 ± 0.8	3.2 ± 1.6	3.2 ± 1.6	3.2 ± 1.6	3.2 ± 1.6
MX4-9	7.8 ± 0.2	9.1 ± 0.8	7.7 ± 0.9	7.6 ± 1.1	7.5 ± 0.8	7.2 ± 0.7
Average ^c	6.8 ± 2.1	7.4 ± 2.3	6.2 ± 3.1	6.0 ± 3.0	6.0 ± 3.0 ^d	5.8 ± 3.1 ^d

^aAverage values and one standard deviation obtained from three replicates.^bMold cracked and bleed water evaporated to some extent.^cAverage value and one standard deviation obtained from all data.^dDoes not include suspect data points from Run MX4-3.

Table H-6. Summary of drainable-water data for grouts prepared from Matrix 5

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX5-1	4.5 ± 0.9	5.9 ± 0.9	3.9 ± 0.8	4.5 ± 0.2	3.7 ± 0.9	3.7 ± 0.9
MX5-2	8.9 ± 0.6	10.7 ± 0.5	9.3 ± 0.6	9.3 ± 0.9	9.1 ± 0.5	8.9 ± 0.2
MX5-3	8.0 ± 0	8.8 ± 0.0	7.6 ± 0.7	7.3 ± 0.2	7.3 ± 0.2	7.3 ± 0.2
MX5-4	7.1 ± 0.6	7.3 ± 0.6	6.3 ± 0.8	6.1 ± 0.9	5.9 ± 0.8	5.7 ± 0.6
MX5-5	5.7 ± 0.2	7.2 ± 0.8	5.5 ± 0.8	5.5 ± 0.8	5.5 ± 0.8	4.5 ± 1.0
MX5-6	4.4 ± 0.7	4.5 ± 0.5	3.1 ± 1.0	3.1 ± 1.0		2.3 ± 0.8
MX5-7	3.1 ± 0.5	3.2 ± 0	2.3 ± 0.2	1.5 ± 0.2		1.5 ± 0.2
MX5-8	4.0 ± 0.8	5.1 ± 1.2	4.0 ± 0.8	3.5 ± 0.8	3.3 ± 0.6	3.1 ± 0.8
MX5-9	5.5 ± 1.0	7.3 ± 1.4	5.9 ± 1.7	5.2 ± 2.0	5.1 ± 1.8	5.1 ± 1.8
Average ^b	5.7 ± 2.0	6.7 ± 2.3	5.3 ± 2.3	5.1 ± 2.4	5.7 ± 2.1	4.7 ± 2.4

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table H-7. Summary of drainable-water data for grouts prepared from Matrix 6

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX6-1	3.1 ± 0.8	3.2 ± 1.1	2.0 ± 1.2	1.5 ± 0.8	1.5 ± 0.8	1.3 ± 0.6
MX6-2	5.2 ± 0.7	5.2 ± 0.7	4.5 ± 1.0	3.6 ± 0.7	3.6 ± 0.7	3.6 ± 0.7
MX6-3	2.9 ± 0.2	3.7 ± 0.2	1.6 ± 0	1.9 ± 0.2	1.6 ± 0	1.6 ± 0
MX6-4	2.8 ± 0.4	3.1 ± 0.8	1.3 ± 0.6	1.2 ± 0.7	1.2 ± 0.7	0.9 ± 0.6
MX6-5	6.9 ± 1.2	7.7 ± 1.5	6.9 ± 1.5	6.3 ± 1.6	6.3 ± 1.6	5.5 ± 1.5
MX6-6	4.3 ± 0.6	4.7 ± 0.6	3.5 ± 0.6	3.1 ± 0.8	2.9 ± 0.6	2.7 ± 0.5
MX6-7	5.9 ± 0.5	6.4 ± 0.8	5.1 ± 0.8	4.7 ± 0.8	4.7 ± 0.8	4.7 ± 0.8
MX6-8	6.8 ± 1.7	6.4 ± 2.1	5.6 ± 2.1	5.2 ± 2.4	5.1 ± 2.2	4.7 ± 2.2
MX6-9	3.2 ± 0.8	3.6 ± 0.6	2.6 ± 0.3	2.2 ± 0.3	2.2 ± 0.3	1.8 ± 0.9
Average ^b	4.6 ± 1.8	4.9 ± 1.8	3.8 ± 2.1	3.3 ± 2.0	3.4 ± 1.9	3.1 ± 1.9

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table H-8. Summary of drainable-water data for grouts prepared from Matrix 7

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX7-1	2.8 ± 1.1	4.0 ± 1.4	3.6 ± 1.4	3.2 ± 1.4	3.1 ± 1.3	3.1 ± 1.3
MX7-2	2.1 ± 0.2	1.7 ± 0.2	1.6 ± 0	1.6 ± 0	1.2 ± 0	0.8 ± 0
MX7-3	4.4 ± 0.7	4.4 ± 0.8	4.0 ± 0.4	3.6 ± 0.4	3.5 ± 0.6	3.5 ± 0.6
MX7-4	5.9 ± 0.5	8.1 ± 0.6	7.7 ± 0.6	7.1 ± 0.6	6.9 ± 0.5	6.8 ± 0.4
MX7-5	4.0 ± 0.7	4.1 ± 0.5	3.5 ± 0.9	3.2 ± 0.8	3.1 ± 0.6	2.8 ± 0.7
MX7-6	2.3 ± 0.2	2.3 ± 0.2	1.2 ± 0.4	1.3 ± 0.5	1.2 ± 0.4	1.1 ± 0.5
MX7-7	4.8 ± 1.1	5.2 ± 1.1	4.7 ± 1.2	4.3 ± 1.2	4.3 ± 1.2	4.0 ± 1.4
MX7-8	2.1 ± 0.2	2.0 ± 0.4	1.6 ± 0	1.2 ± 0	1.2 ± 0	0.9 ± 0.2
MX7-9	4.0 ± 0.8	3.1 ± 0.6	3.1 ± 0.6	3.1 ± 0.6	2.7 ± 0.8	2.7 ± 0.8
Average ^b	3.6 ± 1.4	3.9 ± 2.0	3.4 ± 2.0	3.2 ± 1.9	3.0 ± 1.9	2.8 ± 1.9

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table H-9. Summary of drainable-water data for grouts prepared from Matrix 8

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX8-1	3.3 ± 0.2	3.3 ± 1.0	2.7 ± 1.5	2.7 ± 1.5	2.5 ± 1.3	2.3 ± 1.2
MX8-2	6.5 ± 0.2	7.3 ± 0.2	6.9 ± 0.2	6.7 ± 0.5	6.4 ± 0.4	6.0 ± 0.4
MX8-3	3.5 ± 1.0	3.2 ± 1.4	3.1 ± 1.3	2.8 ± 1.1	2.8 ± 0 ^b	2.6 ± 0.3 ^b
MX8-4	6.7 ± 0.5	6.5 ± 0.2	5.7 ± 0.5	5.6 ± 0.4	5.6 ± 0.4	5.3 ± 0.5
MX8-5	7.5 ± 0.6	7.7 ± 0.8	7.3 ± 1.2	7.1 ± 1.3	6.7 ± 1.0	6.7 ± 0.9
MX8-6	7.5 ± 0.5	8.0 ± 0	7.1 ± 0.2	6.7 ± 0.2	6.4 ± 0	6.4 ± 0.4
MX8-7	7.9 ± 0.6	8.8 ± 1.1	8.3 ± 0.9	8.1 ± 0.8	7.9 ± 0.9	7.6 ± 0.7
MX8-8	5.6 ± 0	5.7 ± 0.6	5.6 ± 0.7	4.8 ± 0.7	4.8 ± 0.7	4.8 ± 0.7
MX8-9	2.5 ± 0.2	2.6 ± 0.3 ^b	2.2 ± 0.3 ^b	2.0 ± 0.6 ^b	1.8 ± 0.3 ^b	1.6 ± 0 ^b
Average ^b	5.7 ± 2.0	6.1 ± 2.3	5.5 ± 2.2	5.3 ± 2.2	5.2 ± 2.1	5.1 ± 2.1

^aAverage values and one standard deviation obtained from three replicates.

^bAverage of only two replicates due to leaking cylinder on third.

^cAverage values and one standard deviation obtained from all data.

Table H-10. Summary of drainable-water data for grouts prepared from Matrix 9

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX9-1	6.7 ± 0.2	7.3 ± 0.2	6.5 ± 0.2	6.4 ± 0.4	5.7 ± 0.2	6.0 ± 0.4
MX9-2	8.0 ± 0	8.9 ± 0.8	8.4 ± 1.1	8.1 ± 1.0	7.9 ± 0.8	7.9 ± 0.8
MX9-3	10.0 ± 0.7	10.9 ± 2.3	9.9 ± 2.2	9.9 ± 2.2	9.7 ± 1.6	9.9 ± 1.9
MX9-4	6.1 ± 1.2	6.7 ± 1.7	6.9 ± 0.5	6.6 ^b	6.2 ^b	6.2 ^b
MX9-5	7.9 ± 0.2	8.5 ± 0.5	7.5 ± 0.2	6.9 ± 0.5	6.8 ± 0.7	6.9 ± 0.5
MX9-6	8.1 ± 0.6	8.7 ± 0.5	7.7 ± 0.5	7.7 ± 0.4	7.5 ± 0.5	7.1 ± 0.8
MX9-7	6.0 ± 1.2	6.5 ± 2.2	5.5 ± 2.0	4.0 ^b	4.0 ^b	4.0 ^b
MX9-8	9.2 ± 0.8	10.1 ± 0.8	9.1 ± 0.9	8.9 ± 0.8	8.9 ± 0.8	8.7 ± 0.6
MX9-9	6.5 ± 0.6	6.8 ± 0.7	5.7 ± 1.0	5.2 ± 0.7	5.5 ± 0.8	5.1 ± 0.8
Average ^b	7.6 ± 1.5	8.3 ± 1.9	7.5 ± 1.7	7.2 ± 1.9	7.1 ± 1.8	7.0 ± 1.9

^aAverage values and one standard deviation obtained from three replicates.

^bAverage value obtained from two replicates.

^cAverage values and one standard deviation obtained from all data.

Table H-11. Summary of drainable-water data for grouts prepared from Matrix 10

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX10-1	8.1 ± 0.2	9.7 ± 0.2	8.4 ± 0.4	8.3 ± 0.5	8.1 ± 0.2	7.7 ± 0.8
MX10-2	7.5 ± 0.5	8.0 ± 0.8	7.1 ± 0.8	6.4 ± 1.1	6.5 ± 1.3	6.4 ± 1.4
MX10-3	7.6 ± 0	7.5 ± 0.5	6.5 ± 0.2	6.4 ± 0	6.1 ± 0.5	6.3 ± 0.2
MX10-4	7.2 ± 0.4	8.1 ± 0.2	6.8 ± 0.4	6.8 ± 0.4	6.5 ± 0.6	6.1 ± 0.2
MX10-5	8.3 ± 0.5	9.3 ± 0.6	8.1 ± 0.8	8.0 ± 0.7	7.9 ± 0.6	7.7 ± 0.6
MX10-6	11.9 ± 0.2	13.3 ± 2.0	12.1 ± 2.3	12.1 ± 2.0	12.0 ± 2.1	11.9 ± 2.2
MX10-7	10.3 ± 0.6	11.2 ± 0.8	9.7 ± 0.8	9.6 ± 0.7	9.5 ± 0.6	9.3 ± 0.5
MX10-8	8.8 ± 0	9.6 ± 0.4	7.9 ± 0.5	7.7 ± 0.9	7.7 ± 0.7	7.7 ± 0.7
MX10-9	10.4 ± 1.1	12.1 ± 0.2	11.5 ± 0.6	11.5 ± 0.5	11.1 ± 0.6	10.9 ± 0.6
Average ^b	8.9 ± 1.6	9.9 ± 2.0	8.7 ± 2.1	8.5 ± 2.2	8.4 ± 2.2	8.2 ± 2.2

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table H-12. Summary of drainable-water data for grouts prepared from Matrix 11

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX11-1	8.4 ± 0.4	9.6 ± 0.4	9.3 ± 0.2	9.1 ± 0.5	8.3 ± 0.5	8.3 ± 0.5
MX11-2	7.2 ± 0.8	8.1 ± 1.2	7.2 ± 1.1	6.9 ± 1.2	6.7 ± 0.9	6.7 ± 0.9
MX11-3	7.5 ± 0.6	7.7 ± 0.8	7.1 ± 0.9	6.7 ± 0.9	6.4 ± 0.8	6.3 ± 0.6
MX11-4	7.7 ± 0.2	8.8 ± 0.4	8.0 ± 0.4	7.7 ± 0.5	7.6 ± 0.4	7.2 ± 0
MX11-5	10.4 ± 0.8	11.1 ± 1.3	10.7 ± 1.3	10.3 ± 1.0	10.1 ± 0.8	9.7 ± 0.8
MX11-6	9.1 ± 1.2	10.3 ± 0.8	9.6 ± 0.8	9.6 ± 0.8	9.5 ± 0.8	9.2 ± 1.1
MX11-7	7.3 ± 0.2	8.0 ± 0.4	7.1 ± 0.5	6.7 ± 0.5	6.7 ± 0.5	6.7 ± 0.5
MX11-8	8.8 ± 0.4	9.3 ± 0.5	8.7 ± 0.6	8.4 ± 0.8	8.0 ± 0.7	8.0 ± 0.7
MX11-9	10.4 ± 1.7	11.7 ± 1.3	11.1 ± 1.2	10.9 ± 1.0	10.7 ± 1.2	10.5 ± 1.0
Average ^b	8.5 ± 1.4	9.4 ± 1.5	8.7 ± 1.6	8.5 ± 1.7	8.2 ± 1.6	8.1 ± 1.6

^aAverage values and one standard deviation obtained from three replicates.

^bAverage values and one standard deviation obtained from all data.

Table H-13. Summary of drainable-water for grouts prepared from Matrix 12

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX12-1	4.9 ± 0.2	5.3 ± 0.5	4.3 ± 0.2	4.0 ± 0.4	4.0 ± 0.4	4.0 ± 0.4
MX12-2	6.5 ± 0.2	6.9 ± 0.5	5.3 ± 0.5	5.3 ± 0.5	5.3 ± 0.5	5.3 ± 0.5
MX12-3	6.5 ± 0.2	7.5 ± 1.2	6.4 ± 1.1	6.4 ± 1.1	6.4 ± 1.1	6.4 ± 1.1
MX12-4	5.6 ± 0	5.6 ± 0	4.0 ± 0.4	4.0 ± 0.4	4.0 ± 0.4	4.0 ± 0.4
MX12-5	4.8 ± 0.8	5.2 ± 0.4	3.2 ± 0	3.5 ± 0.5	3.3 ± 0.2	3.2 ± 0.4
MX12-6	4.8 ± 0.8	4.7 ± 1.3	3.6 ± 1.2	3.6 ± 1.2	3.6 ± 1.2	3.6 ± 1.2
MX12-7	5.6 ± 0.8	5.9 ± 1.3	4.9 ± 1.6	4.9 ± 1.6	4.8 ± 1.4	4.8 ± 1.4
MX12-8	5.2 ± 0.7	5.9 ± 1.3	4.7 ± 1.3	4.7 ± 1.3	4.5 ± 1.2	4.5 ± 1.2
MX12-9	5.7 ± 0.8	5.9 ± 0.9	4.8 ± 0.8	4.8 ± 0.8	4.5 ± 0.8	4.5 ± 0.8
Average ^b	5.5 ± 0.8	5.9 ± 1.1	4.6 ± 1.2	4.6 ± 1.2	4.5 ± 1.2	4.5 ± 1.2

^aAverage values and one standard deviation obtained from three replicates.^bAverage values and one standard deviation obtained from all data.

Table H-14. Summary of drainable-water data for grouts prepared from Matrix 13

Run No.	Drainable water (vol %) ^a observed at					
	2 h	1 d	7 d	14 d	21 d	28 d
MX13-1	8.0 ± 0.8	8.5 ± 1.2	6.9 ± 1.0	6.8 ± 1.1	6.8 ± 1.1	6.8 ± 1.1
MX13-2	10.9 ± 0.5	11.9 ± 0.6	11.1 ± 1.2	10.8 ± 1.4	10.8 ± 1.4	10.8 ± 1.4
MX13-3	8.3 ± 0.5	8.9 ± 0.8	7.1 ± 0.6	6.9 ± 0.5	6.9 ± 0.5	6.9 ± 0.5
MX13-4	6.9 ± 0.5	7.7 ± 0.2	6.7 ± 0.5	6.5 ± 0.2	6.3 ± 0.5	6.3 ± 0.5
MX13-5	11.1 ± 1.6	13.3 ± 0.9	11.3 ± 1.2	11.3 ± 1.2	11.2 ± 1.2	11.2 ± 1.2
MX13-6	7.5 ± 0.5	8.3 ± 0.5	6.4 ± 0	6.4 ± 0	6.4 ± 0	6.4 ± 0
MX13-7	9.2 ± 0.4	10.3 ± 0.2	8.5 ± 0.5	8.4 ± 0.4	8.4 ± 0.4	8.4 ± 0.4
MX13-8	10.3 ± 0.5	10.9 ± 0.6	9.1 ± 1.0	9.1 ± 1.0	9.1 ± 1.0	8.9 ± 1.0
MX13-9	7.5 ± 0.5	8.3 ± 0.2	6.7 ± 0.5	6.7 ± 0.5	6.7 ± 0.5	6.7 ± 0.5
Average ^b	8.8 ± 1.6	9.8 ± 1.9	8.2 ± 2.0	8.1 ± 2.0	8.1 ± 2.0	8.0 ± 2.0

^aAverage values and one standard deviation obtained from three replicates.^bAverage value and one standard deviation obtained from all data.

Appendix I. AVERAGED UNCONFINED-COMPRESSIVE-STRENGTH DATA

Table I-1. Summary of unconfined compressive-strength values^a for grouts prepared from Matrix 1

Run No.	Unconfined compressive strength (psi)
MX1-1	404 ± 34
MX1-2	473 ± 45
MX1-3	415 ± 29
MX1-4	512 ± 38
MX1-5	399 ± 67
MX1-6	483 ± 99
MX1-7	373 ± 55 ^c
MX1-8	489 ± 49
MX1-9	333 ± 20
Average ^b	431 ± 61

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from seven replicates.

Table I-2. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 2

Run No.	Unconfined compressive strength (psi)
MX2-1	439 ± 28 ^c
MX2-2	396 ± 32
MX2-3	348 ± 35
MX2-4	333 ± 22
MX2-5	346 ± 21
MX2-6	370 ± 36
MX2-7	384 ± 23
MX2-8	326 ± 30
MX2-9	397 ± 15 ^d
Average ^b	371 ± 37

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from eight replicates.

^dAverage values and one standard deviation obtained from seven replicates.

Table 1-3. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 2R

Run No.	Unconfined compressive strength (psi)
MX2R-1	391 ± 46
MX2R-2	366 ± 55
MX2R-3	371 ± 50
MX2R-4	382 ± 37
MX2R-5	379 ± 30
MX2R-6	372 ± 45
MX2R-7	329 ± 26
MX2R-8	288 ± 19
MX2R-9	265 ± 19
Average ^b	349 ± 45

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

Table I-4. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 3

Run No.	Unconfined compressive strength (psi)
MX3-1	341 ± 62
MX3-2	306 ± 33
MX3-3	351 ± 53
MX3-4	327 ± 20
MX3-5	452 ± 20
MX3-6	450 ± 15
MX3-7	355 ± 17
MX3-8	335 ± 26
MX3-9	428 ± 13
Average ^b	372 ± 56

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

Table 1-5. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 4

Run No.	Unconfined compressive strength (psi)
MX4-1	492 ± 69
MX4-2	500 ± 40
MX4-3	467 ± 62
MX4-4	469 ± 31
MX4-5	380 ± 22
MX4-6	305 ± 28
MX4-7	427 ± 19
MX4-8	543 ± 25
MX4-9	312 ± 41
Average ^b	433 ± 84

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

Table 1-6. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 5

Run No.	Unconfined compressive strength (psi)
MX5-1	488 ± 44
MX5-2	364 ± 30
MX5-3	475 ± 45
MX5-4	485 ± 34
MX5-5	462 ± 41
MX5-6	437 ± 31 ^c
MX5-7	486 ± 25
MX5-8	380 ± 23
MX5-9	252 ± 17
Average ^b	425 ± 80

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage value and one standard deviation obtained from eight replicates.

Table 1-7. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 6

Run No.	Unconfined compressive strength (psi)
MX6-1	602 ± 42
MX6-2	612 ± 84
MX6-3	449 ± 40
MX6-4	398 ± 22
MX6-5	448 ± 76
MX6-6	443 ± 87
MX6-7	481 ± 30
MX6-8	336 ± 35
MX6-9	488 ± 40
Average ^b	473 ± 89

^aAverage values and one standard deviation obtained from nine replicates.

Table I-8. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 7

Run No.	Unconfined compressive strength (psi)
MX6-1	430 ± 44
MX6-2	443 ± 21
MX6-3	383 ± 30
MX6-4	236 ± 22
MX6-5	367 ± 29
MX6-6	465 ± 35
MX6-7	280 ± 22
MX6-8	450 ± 21
MX6-9	337 ± 23
Average ^b	377 ± 80

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

Table I-9 . Summary of unconfined-compressive-strength values ^a for grouts prepared from Matrix 8

Run No.	Unconfined compressive strength (psi)
MX8-1	451 ± 53
MX8-2	421 ± 34
MX8-3	403 ± 28
MX8-4	392 ± 48
MX8-5	297 ± 24
MX8-6	234 ± 31
MX8-7	315 ± 35
MX8-8	489 ± 52
MX8-9	470 ± 50 ^c
Average ^b	386 ± 86

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from eight replicates.

Table I-10. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 9

Run No.	Unconfined compressive strength (psi)
MX9-1	475 ± 144
MX9-2	417 ± 35
MX9-3	362 ± 85
MX9-4	388 ± 39
MX9-5	367 ± 32
MX9-6	393 ± 47
MX9-7	448 ± 23
MX9-8	269 ± 33 ^c
MX9-9	369 ± 23
Average ^b	388 ± 59

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from eight replicates.

Table I-11. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 10

Run No.	Unconfined compressive strength (psi)
MX10-1	377 ± 55
MX10-2	410 ± 46
MX10-3	412 ± 21 ^c
MX10-4	439 ± 40
MX10-5	329 ± 28 ^c
MX10-6	353 ± 62
MX10-7	511 ± 45
MX10-8	674 ± 32
MX10-9	371 ± 39
Average ^b	431 ± 106

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from eight replicates.

Table I-12. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 11

Run No.	Unconfined compressive strength (psi)
MX11-1	510 ± 75
MX11-2	657 ± 54
MX11-3	618 ± 62
MX11-4	375 ± 43
MX11-5	368 ± 32
MX11-6	386 ± 61
MX11-7	828 ± 32
MX11-8	829 ± 59
MX11-9	645 ± 110
Average ^b	579 ± 183

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

Table I-13. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 12

Run No.	Unconfined compressive strength (psi)
MX12-1	554 ± 49 ^c
MX12-2	517 ± 49
MX12-3	494 ± 46
MX12-4	491 ± 35
MX12-5	597 ± 77
MX12-6	587 ± 49
MX12-7	603 ± 45 ^c
MX12-8	424 ± 22
MX12-9	488 ± 28 ^c
Average ^b	527 ± 73

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

^cAverage values and one standard deviation obtained from eight replicates.

Table I-14. Summary of unconfined-compressive-strength values^a for grouts prepared from Matrix 13

Run No.	Unconfined compressive strength (psi)
MX13-1	484 ± 86
MX13-2	525 ± 44
MX13-3	446 ± 54
MX13-4	610 ± 62
MX13-5	480 ± 18
MX13-6	497 ± 43
MX13-7	511 ± 39
MX13-8	433 ± 30
MX13-9	436 ± 41
Average ^b	491 ± 71

^aAverage values and one standard deviation obtained from nine replicates.

^bAverage values and one standard deviation obtained from all data.

**Appendix J. STATISTICAL COMPARISON OF AVERAGE DATA
OBTAINED ON REFERENCE FORMULATION**

The data are presented in number-line form for ease of comparison. On the number line, the ordinate values are arbitrary to facilitate visual inspection. If any two points are separated by the minimum distance on the number line, then they are statistically different. The minimum distance is determined by the "Q-test."

Fig. J-1. Comparison of average values for 28-d unconfined compressive strength obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 13.75 cm.)

Fig. J-2. Comparison of average values for critical velocity obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 3.35 cm.)

Fig. J-3. Comparison of average values for frictional pressure drop obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 8.5 cm.)

Fig. J-4. Comparison of average values for pump-head pressure obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 11.4 cm.)

Fig. J-5. Comparison of average values for 10-min gel strength obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 5.08 cm.)

Fig. J-6. Comparison of average values for fluid density obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 4.68 cm.)

ORNL DWG 93A-635

Fig. J-7. Comparison of average values for 2-h drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 5.06 cm.)

Fig. J-8. Comparison of average values for 1-d drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 4.99 cm.)

Fig. J-9. Comparison of average values for 7-d drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 5.00 cm.)

Fig. J-10. Comparison of average values for 14-d drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 4.73 cm.)

Fig. J-11. Comparison of average values for 21-d drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 4.73 cm.)

Fig. J-12. Comparison of average values for 28-d drainable water obtained from reference formulation. (Note that the minimum distance along number line for statistical difference between any two points is 4.83 cm.)

**Appendix K. STATISTICAL COMPARISON OF DATA OBTAINED BY AVERAGING
ALL VALUES WITHIN A MATRIX**

The data are presented in number-line form for ease of comparison. On the number line, the ordinate values are arbitrary to facilitate visual inspection. If any two points are separated by the minimum distance along the number line, then they are statistically different. The minimum distance is determined by the "Q-test."

Fig. K-1. Comparison of average values for 28-d unconfined compressive strength obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 6.37 cm.)

Fig. K-2. Comparison of average values for critical velocity obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 4.25 cm.)

Fig. K-3. Comparison of average values for frictional pressure drop obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 18.36 cm.)

Fig. K-4. Comparison of average values for pump-head pressure obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 7.05 cm.)

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Fig. K-5. Comparison of average values for 10-min gel strength obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 7.17 cm.)

ORNL DWG 93A-570R

Fig. K-6. Comparison of average values for fluid density obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 7.85 cm.)

Fig. K-7. Comparison of average values for 2-h drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 4.72 cm.)

Fig. K-8. Comparison of average values for 1-d drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 4.45 cm.)

Fig. K-9. Comparison of average values for 7-d drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 5.13 cm.)

ORNL DWG 93A-575R

Fig. K-10. Comparison of average values for 14-d drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 5.17 cm.)

Fig. K-11. Comparison of average values for 21-d drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 5.46 cm.)

Fig. K-12. Comparison of average values for 28-d drainable water obtained from all matrix data. (Note that the minimum distance along number line for statistical difference between any two points is 6.09 cm.)

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