GROUTING PRECAST
FLOOR SYSTEMS

by

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CTA 9
**INTRODUCTION**

This bulletin has several objectives. The primary one is to determine the current level of practice and the needs of contractors performing grouting of precast floor systems.

A second objective is to assess the cost of site-batching against ready-mixed grouts bought in large volumes (5 cubic yards or more) and pumped into place.

A third objective is to determine the usefulness of chemical admixtures in countering the lower strengths and greater shrinkage which result when water is intermittently added to ready-mixed grouts.

To carry out the first objective, a survey of hollow-core floor system producers and grouting contractors was conducted. Discussion of the results is presented as Chapter 1.

Chapter 2 presents the cost comparison.

Chapter 3 reports the results of laboratory work to determine how various admixtures perform. It also contains a pictorial review of two placing systems used on the West Coast.

Chapter 4 discusses proportioning of grouts and the importance of quality materials.

Also included as an appendix is a three-page Tech Data Sheet to be used by member companies as a handout to clients or plant personnel.
GROUTING PRECAST FLOOR SYSTEMS

SYNOPSIS

The state of the art of grouting precast floor systems is reviewed to evaluate new developments and determine current research needs.

Procedures for assessing the comparative costs of site-batched and delivered (ready-mixed) grout are illustrated.

Included in the bulletin are results of laboratory tests investigating the performance of grouts which have been intermittently dosed with water and/or chemical admixtures.

A discussion of grouting materials and methods outlining recommended procedures for selecting materials and proportioning grouts is presented, in addition to a short Tech Data Sheet suitable for distribution to clients, grouting contractors and plant personnel.
CHAPTER 1

SURVEY

To determine the current level of practice, a survey sheet was mailed to floor systems producers and grouting contractors. The questionnaire contained the following:

1. Does your firm recommend a method of grouting or leave this to contractors?
2. Do you suggest the mix? If so, could you describe the mix?
3. Do you recommend expansion aids? If so, what type?
4. If grout is supplied by ready-mix truck, can you tell us the load size and approximate cost per cubic yard?
5. Are grouts in your area required to develop a minimum compressive strength? If so, how much?
6. Do you know of any firms which grout and place topping simultaneously or use the topping as grout also?
7. Do you know of any grouting equipment made especially for grouting floor panels?

RESULTS

1. Except for producers who erect and grout their own products, most producers do not recommend a method of grout placement. They report that the most common method used is brooming or squeegeeing.

2. The bulk of the producers do, however, recommend a 1:3 cement to sand mixture. Designers and specifiers follow the producers' lead.

3. Grouting expansion aids are seldom used or recommended. Attitudes in the field are that the use of these admixtures is unnecessary and often futile. The argument offered is that the grout has already expanded during transit mixing and cannot expand further in the joint. Contractors remark that using these admixtures can cause problems with inspectors by becoming a center of focus of quality control.
4. When grout is purchased from a ready-mix supplier, the load sizes are typically 5 cubic yards at approximately $65.00 per cubic yard, including 1.5 hours unload time. Smaller loads, say 2 cubic yards, cost from $90-120 per cubic yard.

5. Grout strengths are seldom specified. When specified, strengths are usually 3000 or 3500 psi minimum compressive strength at 28 days.

6. Some firms are filling joints with the topping mix. The mixes are well-graded pea gravel mixes (3/8 in. minus) made with ASTM C33 sand. This practice is not considered to be suitable on decks designed for moving loads such as parking garages or warehouse floors. Moreover, one should be prepared for a greater occurrence of shrinkage cracks in the topping over the joints. When the joints are poured with the topping, supervision must take particular care in following one of the following special techniques:

a. If pumping, aim pump nozzle vertically into the joint so as to force the pea gravel mix into the joint, or

b. Vibrate the mix into the joint making a conscious effort to run the vibrator longitudinally down each joint (tough to do when joint is covered with concrete!).

7. The closest over-the-counter approach to a total mixing and placing system is continuous mixing from "concrete mobiles." These are truck-mounted units with bins for sand and cement. The fresh grout is "continuous-mixed" as opposed to "batch-mixed." Some grouting contractors have fabricated "standard units" for grouting including mixers, pump, and shaped placing nozzles. These are described in Chapter 4.
CHAPTER 2

COST COMPARISONS

The in-place cost of finished grout joints varies considerably with the amount of footage that can be done per day. About 6000 lineal feet per day appears to be a practical upper limit for site-batched grouts. Using ready-mixed grouts and placing with a small-line pump enables placement of up to 14,000 lineal feet per day or 1750 feet per hour. A more usual rate is 10,000 feet per day or 1250 feet per hour.

Cost of Site-Batching 6000 Lineal Feet Per Day

The 6000 lineal foot limit for site-batching reflects the capacity of small mixers and the endurance of the batch man. Most floor grouting crews require four men to do 6000 lineal feet per day including batching, placing, and clean-up.

Many mortar mixers are designed to hold a "two-bag" mix or roughly 5½ cubic feet of grout or mortar. For a hollow-core product with shear key area of 12.0 in.², 6000 lineal feet of joint requires 18.5 cubic yards of grout. To batch and place 18.5 cubic yards requires 91 batches per eight hour shift or one batch every 5.5 minutes. Most mixer men would be hard pressed to maintain such a rigorous schedule. Also, since it may take longer to load and mix one batch than to place it, the three-man placing crew often finds itself waiting on materials.

The cost of site-batching and placing 6000 lineal feet per day (ignoring equipment cost) of 1:3 mix is, approximately:

\[
\begin{align*}
188 \text{ lbs. cement (2 bags)} \times 0.048 &= 9.02 \\
564 \text{ lbs. sand} \times 0.0042 &= 2.37 \\
\text{Total cost} &= 11.39 \times 91 \text{ batches} = 1036 \\
4 \text{ men} \times 8 \text{ hours} \times 24.00 \text{ per hour} &= 768 \\
\text{Total cost} &= 1804
\end{align*}
\]

or \$1804/6000 \text{ ft.} = \$0.30 \text{ per lineal foot (direct cost).}
Cost of Ready-Mixed Grout for 6000 Lineal Feet Per Day

Placing from a pump using a ready-mix truck reduces the men needed to three for 6000 lineal feet per day. These three men require only 4.8 hrs at 1250 feet per hour to do the placement plus another hour for setup and cleanup. The costs are then:

\[
\begin{align*}
18.5 \text{ cubic yards} @ \$65.00 &= \$1,202.00 \text{ Materials} \\
3 \text{ men} \times 4.8 \text{ hrs} \times \$24.00 &= 345.0 \text{ Placing Labor} \\
3 \text{ men} \times 1 \text{ hr} \times \$24.00 &= 72.00 \text{ Equipment Cleanup} \\
\end{align*}
\]

\[\frac{\$1,619.00}{6000 \text{ ft}} = \$0.27 \text{ per foot or 10\% less than site-batching.}\]

Cost for Doing 1000 Lineal Feet Per Day

Ready-mixed – purchasing small quantities of ready-mixed grout and pumping to the point of placement is expensive. For example, 1000 lineal feet per day requires only 3 cubic yards of grout. Ready-mix producers charge a premium of approximately \$35.00 per cubic yard for loads smaller than 5 yards. Thus 3 cubic yards costs approximately \$300.00. The cost for setup and cleanup of equipment to do 1000 feet is the same as for 6000 feet, $72.00. Placement time is reduced by pumping to 0.8 hours. 0.8 hrs. \times 3 \text{ men} \times \$24.00 \text{ hr.} = \$57.60. Thus the cost becomes:

\[
\begin{align*}
3 \text{ cubic yards} \times \$100 \text{ per cubic yard} &= \$300.00 \text{ Materials} \\
\text{Setup and cleanup} &= 72.00 \text{ Labor} \\
\text{Placement} &= 57.60 \text{ Labor} \\
\end{align*}
\]

\[\frac{\$429.60}{1000 \text{ ft}} = 0.43 \text{ per lineal foot.}\]

Site-Batching 1000 Lineal Feet Per Day

On the other hand, site batching and placing this small quantity of material requires only 15 batches of grout. Two men can batch, place, and cleanup 15 batches of 5.5 cubic feet per batch in 3 hours. Thus the costs are:
$11.39 per batch x 15 batches = $170.85 Materials
2 men x 3 hours x $24 per hr. = 144.00 Labor

$314.85 Total

$314.85 \frac{1000 \text{ ft}}{1000} = 0.31 \text{ per lineal foot or } 38\% \text{ less than the cost when purchasing ready-mixed grout.}

Besides being less expensive, site-batching small quantities often results in better quality joints, since the grout is placed almost immediately after mixing instead of being agitated during transit and retempered on site.

The time and cost values used in these examples are obviously not accurate for every locality, but the process of evaluating unit prices illustrated here should be useful to most precasters.
Evaluation of the use of chemical admixtures to restore placeability and maintain shrinkage characteristics:

**Round I:** While in the field, it was observed that some grouting contractors were using admixtures along with water in an attempt to restore pumpability lost during long waiting periods.

The materials being used were either conventional water-reducing admixtures or expansion aids. (In the Northwest, it is not unusual to have inspectors require additional dosages of expansion aid at 30 minute intervals). Very little field testing has been done on this practice. A few cube test results were available but there was a lack of information on shrinkage.

To evaluate the practice, several 2 cubic foot batches were produced in a rotating drum mixer. Each batch was treated with additions of water or admixtures at 30 minutes and 1 hour after batching to simulate field practice. Compressive strength and shrinkage were tested. The grout proportions were the recommended 1:3 cement to sand. Coarse paving sand with F.M. of 3.17 was used.

The admixtures used were Intraplast-N, an expansion aid, or Zeecon, a lignin-based water-reducer. Mixes were proportioned to produce a highly plastic pumpable grout. Pumpability was judged using a modified Corps of Engineers Flow Cone CRD-C79.

The flow cone was truncated to allow an opening of 1 in. diameter instead of the standard 0.5 in. Figures 1A and 1B show the standard cone and the modified field version. Grout was judged pumpable when it passed through the opening under gravity flow. Figures 2 through 5 show the admixture test results.
RETEMPERED CONTROL MIX

As expected, the control mix showed large shrinkage values, becoming larger with each addition of water, as shown in Figure 2. The first addition (equal to 3 gallons per cubic yard) increased the shrinkage over initial by 3% and decreased strength by 4%. The second addition was equal to 1.0 gallon per cubic yard or 4.9 liters per cubic meter. Shrinkage and strength changed by 23% and 19% respectively. It appears that the increased shrinkage and decreased strength after the second addition may be due more to continuous agitation than to the small quantity of water added.

Figure 1A: Standard CRD-C79 Flow Cone  Figure 1B: Modified cone for field use

Figure 2: Shrinkage and strength of control mix
REPEATED DOSAGE OF INTRAPLAST-N

Figure 3 shows the results of an initial dose of Intraplast-N at 1% x weight of cement, the same mix remixed with water at 30 minutes to restore pumpability, and with a second addition of Intraplast-N at one-half the original dose at 1 hour.

The control batch with initial dose of expansion agent displayed shrinkage of 750 micro-inches at 28 days and 4000 psi compressive strength. Adding 1.5 gallons of water per cubic yard increased the shrinkage by approximately 12% and decreased strength marginally (5%). The second addition of Intraplast-N produced much larger shrinkage (25%) than the original dose and reduced the strength of 28-day test cubes by 34%.

If expansion aids such as Intraplast-N are used, redosing at intervals should be avoided.

REPEATED DOSAGE OF WATER REDUCER

Figure 4 shows the effect of using Zeecon in the fresh batch, adding 3 gallons of water per cubic yard at half an hour, and a second dose of admix at one hour after batching. The addition of water enlarged shrinkage by 12% and reduced strength only slightly. The addition of a second dose of Zeecon resulted in a very slight change in shrinkage and no change in compressive strength.
Figure 4: Effect of repeated dosage of water-reducer

COMPARISON OF TREATMENTS

Figure 5 compares the shrinkage and strength of the plain grout to the admixed grouts. Both the water-reduced and expanded mixes reduced shrinkage over the non-admixed control by 4% and 16%, respectively. Strengthwise the Zeecon additions maintained the compressive strength, while the Intraplast-N contributed to a 21% decrease. Although the Intraplast-N mix produced the smallest shrinkage it also produced the weakest grout. The water-reduced mixture produced smaller shrinkage values at 28 days than plain grout while maintaining the strength.

Figure 5: Comparison of three control mixes (no redosage)
Round II: The second part of this study compares the use of Zeecon water-reducer and aluminum powder at 0.01% x weight of cement to a polymer admix used with Intraplast-N, the expansion aid. This combination is often found in the Northwest. The grouts were mixed in the morning and intermittently agitated during the day. Admixes were added at the indicated intervals. Figures 6 and 7 show the results. No shrinkage tests were performed.

ZEECON/ALUMINUM POWDER MIX

Figure 6 shows that all the characteristics tested were abused by this treatment. Throughout the long delay period the mixes appeared "fresh" and workable. Appearance and workability are obviously inadequate as judgment criteria for inspectors.

![Figure 6: Zeecon/aluminum powder mix](image-url)
POLYMER/EXPANSION AGENT MIX

Figure 7 shows the data displayed in the same fashion. This mix was held for seven hours. Although it lost slump quickly, it appeared cohesive and pumpable upon additions of the admixtures. The data plainly show that, although the mix appeared usable, the 7-day strength was reduced by more than 50%.

Figure 7: Polymer/expansion agent mix
PICTORIAL REVIEW OF TWO VIABLE PLACING SYSTEMS

In an earlier effort to develop high quality grouts and grouting equipment, CTA developed a portable grout placing machine to place and vibrate low-slump grouts. The prototype machine is shown below.

Figure 8: Prototype machine

While the machine works, it appears that it is already outdated. The methods used by Spancrete of California and Air-Pak Concrete (pumping the grout to the deck and filling the joints with a shaped nozzle) are faster and therefore more economical. These methods are illustrated in the pictorial review (overleaf).
A. Spancrete Of California

A-1: For small jobs, less than 2.0 cubic yards, Spancrete mixes on site using a conventional mixer and grout mixed right on the deck.

A-2: Larger quantities are purchased from the ready-mix dealers and pumped through a Mayco pump with a 2.0 in. line.
A-3: Once the pump line reaches the deck it is fitted with a swivel connection to make handling easier.

A-4: The line is further reduced to 1 in. inside diameter at the placing nozzle. The nozzle is shaped to fit the joint.
A-5: Placing is fast and effective using this technique. Spancrete’s crew can place 10–15,000 lineal feet per day.

A-6: Before grouting is started, the Spancrete crew levels the planks using a two-man system.
A-7 & 8: One man remains topside with a drill motor while another stays underneath to hold the bolt and plate in place till tightened up.

The operation is fast and effective.
B. Air-Pak, Concrete Tech System

CTC has been working with Air-Pak Concrete, a grouting contractor, to develop a system similar to Spancrete's. As in Spancrete's operation, the grout is either mixed on site or purchased from a ready-mix dealer. The grout is pumped onto the deck using a Mayco or other pump with a 2 in. line.

B-1: Small jobs are site mixed, using a homemade "concrete-mobile."

B-2: On larger jobs, the grout is purchased and pumped.

B-3: Like the Spancrete system, the grout is placed through a nozzle shaped to fit the joint. The system is equipped with a remote control unit to activate the pump.
B-4: The end product appearance using this system is excellent, particularly in untopped applications. Topped applications do not require as much cleanup.

B-5 & 6: The system works well even on tall buildings. The pictures below were made on the 10th floor of a Seattle hotel.

Notice the cleanliness of the operation. The system enables placement of 5 cubic yard loads in 30-45 minutes. A more usual rate would be about 45-60 minutes.
While developing mixtures for the system, several trial mix designs were used. The most easily handled and highest strength mixture was one containing 6 sacks of Type I cement, 3000 lbs of sand, 84 lbs of Class C fly ash, and 0.9 lbs of Master Builders LL 612 grout fluidifier. The picture below shows the workability of the above mix. The mix is designed to be a no-sag material of stiff consistency (similar to toothpaste). This mix produced 5500 psi at 28 days.

B-7: The consistency of grout being exuded from a 1.0 in. line.
CONCLUSIONS FROM LABORATORY AND FIELD STUDIES

1. The 1:3 grout mix in common usage produces adequate strength and acceptable shrinkage unless abused by delayed additions of water or admixtures.

2. Cement contents may be reduced if the sand is well-graded, a water-reducing admixture is used, and reasonable quality control procedures are observed.

3. Conventional water-reducing admixtures, with moderate retardation characteristics, should be used under any of the following circumstances:
   a. Grout strength > 3500 psi is specified
   b. Mixing and placing temperatures exceed 60°F
   c. Time between mixing and pumping exceeds 45 minutes (shorter with Type III cement)
   d. A 1:4 or leaner mix is used.

4. The use of an expansion aid is not justified unless the grout key surfaces have smooth form finishes.

5. If expansion aids are used, they should be added shortly before the grout is placed and the grout fully placed in no more than 15 minutes.

6. Retempering grouts with water and/or admixtures is generally a poor practice; however, negligible damage is done to the grout by a single redosing of a retarding-type water-reducing admixture at one-half the original dose. This should extend the plastic age of the grout by 15 to 30 minutes depending on temperature (subject to testing by the Grouting Subcontractor and Grout Supplier).

7. Improving plasticity by means of fly ash as well as a retarding-type water-reducer should be considered when pumping distances are long and/or sand gradation is harsh.
CHAPTER 4

DISCUSSION OF GROUTING MATERIALS AND METHODS

FACTORS INFLUENCING GROUT PERFORMANCE

The grout used for precast floor systems is essentially a fluid mortar composed of sand, cement, and water. Grouts are typically looser (wetter) than the mortars used to join brick or block structures, but they serve the same purposes. Primarily, they create a tight seal between units while joining the units for load sharing, while they also strengthen the structure by bonding reinforcement, ties, and anchor bolts so that they perform integrally with the floor system.

As grouting begins, the cementitious material must flow into the joint, immediately occupying the volume available. The mortar and paste must spread to fill all surface irregularities and surround any reinforcing steel. During the filling and consolidating operations, grouts are subjected to many factors, only a few of which are controllable by the grouting contractor. Figure 9 shows the main factors.

![Diagram of factors influencing grout performance](image)

Figure 9: Factors influencing grout performance
As shown above, when adjacent precast units are absorptive, the grout is subjected to suction which can reduce the water-cement ratio at the bond line, improving strength. Non-absorptive units will reject the excess mixing water, causing higher w/c ratios and reducing strength at the interface. When grouting non-absorptive units, the excess mix water added for workability must bleed off, resulting in settling and longer times to initial set of grouts. Absorptive units tend to cause earlier stiffening, reducing settlement and shrinkage. The temperature of adjacent units also plays a part in the performance of grouts in place. For instance, grout placed in warm dry joints in the summertime stiffens much faster than grouts placed in cold, damp joints in the winter. Thus summer grouting may require higher water contents while winter grouting may require removal of water from the mix to prevent excessive settling.

Evaporation of water from the top grout surface occasionally leaves plastic shrinkage cracks in grouted joints. These cracks are generally not deep and are a problem only because they are unsightly.

The few factors controllable by contractors are consistency or flowability of the fresh grout, the materials used in the mix (including proportions of the mixture and the gradation of the sand), the temperature of the fresh grout, and finally the compressive strength. Of these factors, consistency appears to be the most important. These controllable factors are discussed below.

CONSISTENCY OF FRESH GROUTS

The "loose" consistency of the grout is important to proper placement since the grout must flow into the small areas of shear keys. The use of "stiff" mortars typical to the concrete block construction can lead to waterproofing problems and occasionally structural problems if the joints are not well-filled and compacted.

The consistency of grouts can be measured with a standard flow table. ASTM C230 contains specifications for flow tables.

In the flow table test, a truncated cone of mortar is placed on the flow table top. The table and mortar are raised and dropped 25 times through a 1/2 in. fall. The final diameter of the mortar is measured and the consistency is calculated as the percentage of increase in mortar diameter.
Current specifications often require laboratory test mortars to have a consistency of 110 - 115%. In the field, a flow of 120 - 130% is necessary to produce a highly plastic, placeable grout suitable for pumping. While the drop table is impractical for use in the field, it can be used to establish the proportions for grouts and to correlate slump with compressive strengths for 2 by 2 in. cube specimens (ASTM C109).

Another test used to develop proportions is the "water retentivity test" described in ASTM C91. In this test, a sample of grout is measured for flow characteristics. A second sample of grout is then subjected to suction, remixed, and measured for flow. The second value is divided by the first value and multiplied by 100 to give a value of water retention. Specifications generally require a value of 70. High water retention is desirable for grouts placed on hot, windy days. Low water retention is desirable in cold weather. When grouts have good retentivity, they stiffen slowly. Grouts that stiffen rapidly form cracks and open capillaries through which water can flow.

As a field check, Stamatopoulos and Kotzias*, have recommended the use of a "mini-slump" test. This test is performed with the conical mold and tamping rod used in determining the absorption of fine aggregate (ASTM C128). The mold is in the form of a frustrum of a cone 40±3mm wide at the top, 90±3mm wide at the base and 75±3mm high. The tamper weighs 340 gm (12 oz) and has a circular face 25±3mm (1±1/8 in.) in diameter.

The mold is placed on an impermeable base and filled in three layers of equal thickness. The first two layers are tamped lightly 10 times, the final layer 5 times. The surface of the mortar is then struck off using a straight edge, the mold lifted carefully and mini-slump measured as the difference between the height of the mold and the height of the center of the mortar cone.

Correlation of the "mini-slump" test is shown in Figure 10 below. While the method has not become a standard test, it can be very useful to the grouting contractor as a control tool.

MATERIALS USED IN GROUT

Portland Cement

ASTM C150 covers types of cement generally used in grouts. Type I, I-II, and III are frequently used in grouts for floor systems. Type I-II is generally used year round except in cold climates, where Type III is recommended. Type III cement ordinarily requires slightly more water per cubic yard than Type I while producing equivalent cube strengths. Masonry cements are sometimes used in grouts but they should not be used unless tests have first confirmed their suitability. Masonry cement often contains such materials as hydrated lime, air entraining agents and occasionally water repelling agents.

Sand

The sand used in preparing grouts can be natural or manufactured. Natural sand, where available, is preferred due to its usually rounder particle shape. Manufactured sand is generally more angular, requiring more water for a given consistency. When poorly graded sands are used, settlement can be excessive due to bleeding. When this happens at the interface of non-absorptive units, the bond line may shrink away from the interface, leaving an open space through the joint or the grout may crack behind the bond line, also destroying watertightness.

Figure 10: Correlation of mini and standard slump tests.
Adapted from ACI Journal, September 1971
Gradation

The sand for grouts is usually specified or defined according to ASTM C144, "Standard Specifications for Masonry Mortar," or ASTM C33, "Standard Specifications for Concrete Aggregates." Gradation limits from the standards are shown as Table 1 below. The Uniform Building Code also specifies these gradations under section 24.23.

### TABLE 1

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>ASTM C144</th>
<th>ASTM C33</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in. (9.5 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>100</td>
<td>95 - 100</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>95 - 100</td>
<td>80 - 100</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>---</td>
<td>50 - 85</td>
</tr>
<tr>
<td>No. 30 (800 microns)</td>
<td>---</td>
<td>25 - 60</td>
</tr>
<tr>
<td>No. 50 (300 microns)</td>
<td>---</td>
<td>10 - 25</td>
</tr>
<tr>
<td>No. 100 (150 microns)</td>
<td>25 max.</td>
<td>2 - 10</td>
</tr>
</tbody>
</table>

* Additional requirement that not more than 45% be retained between two consecutive screens.

In comparing the standards, it is obvious that ASTM C33 requires much tighter regulation of gradation. This results in better control of workability.

However, the limits shown in the table are far from optimum. The table below shows the gradations recommended by CTA. Good gradation reduces separation and bleeding as well as unit water content.

### TABLE 2

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>MASONRY MORTAR</th>
<th>CONCRETE AGGREGATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in. (9.5 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>100</td>
<td>95 - 100</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>95 - 100</td>
<td>80 - 100</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>70 - 100</td>
<td>60 - 75</td>
</tr>
<tr>
<td>No. 30 (800 microns)</td>
<td>40 - 75</td>
<td>35 - 45</td>
</tr>
<tr>
<td>No. 50 (300 microns)</td>
<td>10 - 35</td>
<td>15 - 25</td>
</tr>
<tr>
<td>No. 100 (150 microns)</td>
<td>2 - 15</td>
<td>2 - 5</td>
</tr>
</tbody>
</table>
In addition to ASTM C144 and C33, ASTM C404, "Aggregates for Masonry Grout," is occasionally encountered. This standard allows the use of aggregate sizes No. 8 or No. 89 (pea gravel) in coarse grouts. Such grouts can be used successfully in floor joints if sufficient joint width is available. These grouts should be proportioned the same way concrete is since they are more like "wet concrete" than grouts. Table 3 sets out the allowable grading limits for coarse aggregates in grouts.

**TABLE 3**

ASTM C404 ALLOWABLE LIMITS FOR COARSE AGGREGATES FOR GROUTS

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>PERCENT PASSING</th>
<th>PERCENT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE NO. 8</td>
<td>SIZE NO. 89</td>
<td></td>
</tr>
<tr>
<td>1/2 in. (12.5 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3/8 in. (9.5 mm)</td>
<td>85 - 100</td>
<td>90 - 100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>10 - 30</td>
<td>20 - 55</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>0 - 10</td>
<td>5 - 30</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>0 - 5</td>
<td>0 - 10</td>
</tr>
<tr>
<td>No. 30 (600 microns)</td>
<td>---</td>
<td>0 - 5</td>
</tr>
</tbody>
</table>

**Deleterious Substances**

Pit-run sands often contain harmful substances such as clay or lightweight particles with specific gravity less than 2.0. Table 4 below sets out some of these materials and the methods used to evaluate the sand.

**TABLE 4**

DELETERIOUS SUBSTANCES

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>EFFECT ON GROUT</th>
<th>ASTM TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>Affects workability, durability, strength</td>
<td>C142</td>
</tr>
<tr>
<td>Lightweight materials; coal, lignite, and others</td>
<td>Same as above</td>
<td>C123</td>
</tr>
<tr>
<td>Organic impurities</td>
<td>Affects setting and hardening, may cause deterioration</td>
<td>C40</td>
</tr>
<tr>
<td>Silt and other powdered materials</td>
<td>Affects durability and workability</td>
<td>C117</td>
</tr>
</tbody>
</table>
Lime

While masons often add hydrated lime to plasticize mortars, the use of lime as plasticizer for grouts should be discouraged, particularly in joints open to weather. The addition of lime can lead to unsightly efflorescence on the bottom side of floor systems, while the high alkalinity can cause damage to painted ceilings.

Water

Water should be potable. This precludes water with alkalis, acids, salts, or other organic substances that might affect setting and strength development. Dirty or brackish water can be the source of efflorescence or scum on the finished joints.

Admixtures

Water-Reducing

Water-reducing admixtures should be used whenever possible. These admixtures should meet requirements of ASTM C494, "Chemical Admixtures for Concrete," Type A water-reducing, or Type D water-reducing and retarding admixtures. Further information on usage is presented in Chapter 3, "The Use of Admixtures." During cold weather an accelerating admixture meeting ASTM Type E requirements should be considered or the Type I cement replaced with Type III.

Pozzolans

The use of fly ash as an admixture in grouts and mortars is an old practice in the brick and block building industries. The fly ash is used to combat efflorescence in the joints of block buildings and to help combat shrinkage. It is not used as a cement replacement. Grouting contractors occasionally use fly ash as a pump aid to fatten harsh mixes. The use of pozzolans requires tighter quality control procedures to insure against overdosing.
PROPORTIONING GROUT MATERIALS

1:3 Mortar Mix

As mentioned in Chapter 1, the grout recommended by precasters for use in floor joints is a 1:3 mortar mix. This mix appears to derive from ASTM C270, "Standard Specifications for Unit Masonry." The standard recognizes five types of mortars: M, S, N, O, and K. Type M mortar is a high strength mortar intended for use where high compressive loads, severe frost action, reinforced joints, or seismic motion is expected. It is also used for below grade structures, such as manholes or catch basins. According to ASTM C270, Type M mortar must develop 2500 psi in compression at 28 days when tested as 2 in. cubes (ASTM C109).

According to the standard, aggregate proportions for Type M mortar are not less than 2-1/4 times nor more than 3 times the sum of cement used. Only enough water is added to reach the desired consistency. CTA recommends that the water content never exceed 5 gallons per sack of cement. When water demand is larger than 5 gallons per sack, a water-reducing admixture should be used.

Proportions are batched either by weight or volume. Site-batching is almost always by volume. Ready-mixed grouts are weigh-batched. Experience has shown that while volumetric measurements are generally uniform from batch to batch, actual weights will vary by as much as 10 - 20% due to sand bulking. Thus, volumetric batching is recommended only when weigh batching is not available. Weigh batching allows for correction of the sand weight from dry to wet and allows much finer control of uniformity of yield and strength. While either system can produce a strong flowable grout, variations in volumetric batching produce large fluctuations in the yield of grout from day to day. This can increase the use of cement substantially.

The Use of Leaner Mixes

As a general rule, the use of the 1:3 mix is not economical since it usually contains about 900 lbs (9.5 sacks) of cement per cubic yard. The use of a leaner mix, say seven sacks, reduces the cost by approximately 25%. Additionally, the high paste content of the 1:3 mix (approximately 38% of the total volume) contributes to greater shrinkage than the leaner mix, (approximately 32% of the total volume).
Leaner mixes are acceptable where joints are unexposed to weather, such as indoors or under high quality topping, provided proof of performance is available. Where grout is exposed to weather or subjected to standing water, the 1:3 mix is preferred since it will always be less permeable than lean mixes.

**TEMPERATURE OF FRESH GROUT**

The temperature of fresh grout should be 50-70°F to avoid premature stiffening in warm weather and delayed stiffening in cool weather. Either icing the mixture, or using hot water may be required to stay in this range. Grouts placed in cold weather or against cold units are particularly sensitive to damage from freezing during the period immediately after placement. Since the unit water content of grouts is usually much higher than that of concrete, grouts are much more subject to damage by expansion.

**PLACING**

Placing the grout into the joint can be done by pouring, brooming, or squeegeeing grout into the joint followed by "puddling" with a stick or metal rod.

When large quantities are to be placed in one day, the use of a small pump with 2.0 in. line and nozzle shaped to fit the joint is recommended.

Joints should be finished up by shoveling off any excess and tooling or striking the joint with a mason's trowel. This last step is only important in untopped applications.

**CURING**

Since joints in floor systems are usually narrow and deep, special curing is necessary only in cold weather. This is based on the assumption that the grout continues to hydrate until the relative humidity within the grout drops to less than 80%. Since most floor joints are covered by topping concrete within a few days, no special curing is normally needed.
APPENDIX

CONCRETE TECHNOLOGY ASSOCIATES

TECH DATA SHEET
CONCRETE TECHNOLOGY ASSOCIATES (CTA) TECH DATA SHEET

The tech data information presented here is for use by contractors and engineers. It is intended as guideline information only, not as a specification. Engineering judgment must be used in the application of this information to any specific situation.

MATERIALS RECOMMENDED


Water: Potable, not more than 5 gallons per sack of cement. Maximum water-cement ratio of 0.44.

Admixtures: ASTM C494 Type A, Water-Reducer, as needed to meet water-cement ratio requirements.

Sand: Should meet gradation requirements of Uniform Building Code Standard No. 24-23, Aggregates for Grout. Figure 1 shows the gradations. Size No. 1 is the same as ASTM C-33, Standard Specification for Concrete Aggregate, fine aggregate provision. It is the most readily obtainable gradation. Sizes No. 8 and No. 89 should only be used when joints are wider than 1.0 inch. Sand should also comply with section 24.2304 and 24.2305 below.

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>AMOUNTS FINER THAN EACH LABORATORY SIEVE</th>
<th>SUMMER SPANNING, PERCENT BY WEIGHT</th>
<th>FINE AGGREGATE</th>
<th>COURSE AGGREGATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size No. 1</td>
<td>Size No. 2</td>
<td>Natural</td>
<td>Manufactured</td>
<td>Size No. 8</td>
</tr>
<tr>
<td>1/4-inch</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>95 to 100</td>
</tr>
<tr>
<td>3/8-inch</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>95 to 100</td>
</tr>
<tr>
<td>No. 4 (4.76-mm)</td>
<td>95 to 100</td>
<td>100</td>
<td>100</td>
<td>95 to 100</td>
</tr>
<tr>
<td>No. 8 (3.38-mm)</td>
<td>90 to 100</td>
<td>100</td>
<td>100</td>
<td>90 to 100</td>
</tr>
<tr>
<td>No. 16 (1.19-mm)</td>
<td>50 to 80</td>
<td>100</td>
<td>100</td>
<td>50 to 80</td>
</tr>
<tr>
<td>No. 30 (0.95-microns)</td>
<td>25 to 50</td>
<td>100</td>
<td>100</td>
<td>25 to 50</td>
</tr>
<tr>
<td>No. 50 (0.15-microns)</td>
<td>10 to 30</td>
<td>100</td>
<td>100</td>
<td>10 to 30</td>
</tr>
<tr>
<td>No. 100 (0.05-microns)</td>
<td>2 to 10</td>
<td>100</td>
<td>100</td>
<td>2 to 10</td>
</tr>
<tr>
<td>No. 200 (0.025-microns)</td>
<td>---</td>
<td>100</td>
<td>100</td>
<td>---</td>
</tr>
</tbody>
</table>

Deleterious Substances

Sec. 24.2304. The amounts of deleterious substances in either fine or coarse aggregate shall not exceed the following.

<table>
<thead>
<tr>
<th>PERMISSIBLE CONTENT (Maximum percent by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DELETERIOUS SUBSTANCES</td>
</tr>
<tr>
<td>Clay lumps ................................................</td>
</tr>
<tr>
<td>Lightweight particles, other than blast-furnace slag,</td>
</tr>
<tr>
<td>Flooding on liquid having a specific gravity of 2.0.</td>
</tr>
</tbody>
</table>

Organic Impurities

Sec. 24.2305. The fine aggregate shall be free from injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and passing a color darker than the standard shall not be used.

Figure 1: UBC Grading requirements. Taken from Uniform Building Code, 1982.
Lime: Not recommended.

Fly Ash: Not recommended as cement replacement. When used as an admixture or pumping aid, should not exceed 10% by weight of cement.

PROPORTIONING

In cases where sand quality or gradation is marginal or unknown and/or controls in batching and mixing are loose, proportions should be in accord with ASTM C476, Standard Specifications for Mortar and Grout for Reinforced Masonry, except that lime is not recommended (see Table 1).

TABLE 1
ASTM C476 GROUT SPECIFICATIONS

<table>
<thead>
<tr>
<th>Grout type</th>
<th>Portland cement**</th>
<th>Lime †</th>
<th>Aggregate††</th>
<th>Fine</th>
<th>Coarse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine</td>
<td>1</td>
<td>0-1/10</td>
<td></td>
<td>2½ to 3 times the sum of the volumes of cementitious materials</td>
<td>—</td>
</tr>
<tr>
<td>Coarse</td>
<td>1</td>
<td>0-1/10</td>
<td></td>
<td>2½ to 3 times the sum of the volumes of cementitious materials</td>
<td>1 to 2 times the sum of the volumes of cementitious materials</td>
</tr>
</tbody>
</table>

EXCEPTIONS TO PROPORTIONING

Exceptions need not be harmful provided that:

1. Sand grading and quality are known to be acceptable
2. Water and cement contents are well-controlled
3. Duration between mixing and placing is not lengthy
4. Strength performance is verifiable through testing

When exceptions are considered, the minimum permissible cement content should be 7 sacks (658 lbs) per cubic yard.

Exceptions should be judged on the basis of laboratory test data indicating acceptable past performance.

Mixing: Should be done in a mechanical drum mixer or transit mixed in agitating truck. Mixing period in small mixers should be not less than 3.0 minutes.
Consistency: As required, but should be at least 6.0 in. slump to assure full flow into the cavity.

Placing: As appropriate to volume required. Recommended method is to use a small pump with 2 in. line to transport and place through a nozzle shaped to fit the joint. Grout should not be placed when the ambient temperature is less than 40°F (4°C). Grout more than 1.5 hours old should not be placed. Redosing with one-half the original dose of water-reducing agent may be permitted once per batch, subject to test data showing that the minimum specified cube strength will be attained.

Temperature: Fresh grout should be 50 – 70°F (10 – 21°C).

Curing: Fresh grout should be protected from freezing, otherwise no special curing is needed.

Strength: A minimum acceptable average compressive strength of 3000 psi based on tests of three 2 in. cubes at 28 days is recommended. Cubes should be made, cured and tested in conformance with ASTM C109, Compressive Strength of Hydraulic Cement Mortars.