Masonry 101 - Grout

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

2

Course Description

This course provides a comprehensive introduction to grouts and grouting for new masonry construction, especially for those who have little to no experience with masonry but find themselves needing to design or review projects.

It describes the purpose of grout for masonry construction, both fine and coarse, as well as conventional and self-consolidating mixes, and desirable properties for all of these.

It describes the materials that comprise grout and explains how grouts are specified, batched, mixed, and placed.

Test methods for grout and preparation of test specimens are explained.

3

Learning Objectives

- Describe fresh and hardened grout properties for new masonry construction
- Review the materials used to make grout for masonry and understand the specifications for each
- Overview the two methods for specifying grout for new masonry construction
- Discuss typical grout placement procedures
- Introduce common grout test procedures

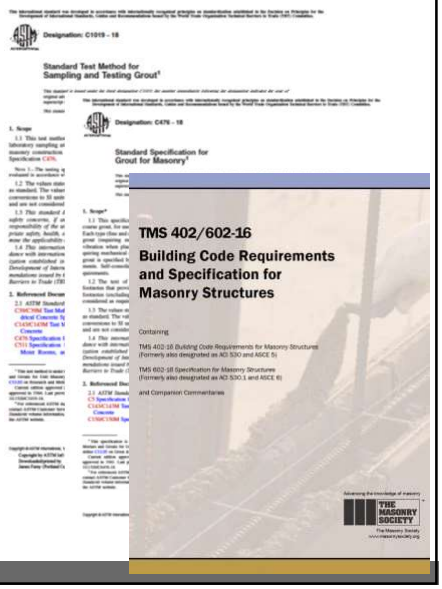
4

Grout & Grouting

5

Grout Introductory Remarks

- ASTM C476 grout specification
- Main contents:
  - Materials
  - Grout type and proportions
  - Measurement and production
- Two types of grout are covered:
  - Fine and coarse (refers to aggregate size)
- Grout can be:
  - Conventional Grout – requires consolidation
  - Self-Consolidating Grout (SCG) – flowing
- ASTM C1019 sampling and testing grout
- TMS 402/602 Code and Specification



Grout & Grouting

- Grout is used to fill masonry cavities
- Bonds units, mortar, and reinforcement into a single composite assemblage
- Is an **essential component of reinforced masonry** and an optional component of unreinforced masonry
- Grouting can be done in some cavities (partially grouted) or in all cavities (fully grouted)

7

Grout

- To fill cavities, it must be fluid
- To bond the assembly, it must have adequate strength
- Definition: A fluid mixture of cementitious materials and aggregate to which water has been added such that the mixture will flow without segregation of the constituents

8

Grout Materials

- Cementitious materials
  - Cements
  - Supplementary cementitious materials (SCMs)
- Aggregate
  - Fine (sand)
  - Coarse (gravel)*
- Water
- Admixtures*

*Not always used

9

Cementitious Materials

- Portland Cement (ASTM C150)
- Blended Cement (ASTM C595)
- Hydraulic Cement (ASTM C1157)
- Coal Fly Ash or Raw Calcined Natural Pozzolan (ASTM C618) – grout may have up to 40% fly ash or natural pozzolan
- Slag Cement for Use in Concrete and Mortars (ASTM C989) – grout may have up to 70% slag cement
- Lime (ASTM C207 or C5)

10

Cement Designations

- Portland Cement ASTM C150
  - Types I, II, III and their air-entrained counterparts
- Blended Cement ASTM C595
  - Types IS, IP, IL, IT
  - Special properties of air entrainment (A) or sulfate resistance (MS) or (HS) are allowed
- Hydraulic Cement ASTM C1157
  - These materials can be portland or blended cement
  - Types GU, HE, MS, and HS

3. Materials

3.1 Materials used as ingredients in grout shall conform to the requirements specified in 3.1.1 – 3.1.5.

3.1.1 *Cementitious Materials*—Cementitious materials shall conform to one of the following specifications:

3.1.1.1 *Portland Cement*—Type I, IA, II, IIA, III, and IIIA of Specification C150/C150M.

3.1.1.2 *Blended Cements*—Type IL, IS(<70), IP, IT(S<70), or blended cements with special properties designated by (A), (MS), or (HS), or a combination of (A) and (MS) or (HS), as appropriate, of Specification C595/C595M.

3.1.1.3 *Hydraulic Cements*—Types GU, HE, MS, or HS of Specification C1157/C1157M.

11

Some Comments about Grout & Sustainability

- Grout mixes usually have high SCM content
  - Fly ash, slag
- Why use them?
- Improve grout properties
  - Strength and workability
- Environmental benefits
  - Reuse waste/byproducts
  - Lower CO_2 footprint of mixes
- Economy
- Emerging C595 blended cement: Type IL, or PLC

Portland-limestone cement, or PLC

- Contains 5% to 15% ground limestone
- Optimized for performance by cement manufacturers
- PLC can be used at a 1:1 replacement for ordinary portland cement (OPC) in concrete or grout
- Allows for same SCM content as ordinary portland cement mixes
- Offers a savings of CO_2 footprint of about 10% for OPC portion

Lime

- Lime assists with:
  - Workability
  - Water retention
- Maximum allowed: 1/10 part (by volume)
- Hydrated Lime
  - ASTM C207
  - Type S
- Quicklime (lime putty) – much less common now
  - ASTM C5

13

Admixtures

- Prohibited in grout, *unless specifically approved for project*
  - Shrinkage-compensating materials are common grout admixtures (sometimes called grout aids) and offset shrinkage due to water loss
  - Accelerators reduce required protection time in cold weather
  - Retarders delay set for hot weather or long deliveries
  - High-range water-reducing admixtures (HRWR, superplasticizers) increase workability, placeability

14

Admixtures - continued

- Pumping aids
  - Acceptable, but must be identified by brand, quality, quantity
- Air-entraining admixtures (and AE materials)
  - Not recommended where grout is used to bond masonry units to reinforcing bars
- No antifreeze compounds allowed
  - Often ineffective prevention against cold temperatures
  - Often contain high amounts of chloride

Aggregate

- ASTM C404 – Aggregates for Masonry Grout
- Fine aggregate – sand
  - Natural or manufactured
- Coarse aggregate – gravel, crushed stone
  - 3/8 in. maximum size
  - Natural or manufactured

Aggregate Grading per C404

TABLE 1 Grading Requirements

Sieve Designation	Amounts Finer than Each Laboratory Sieve Designation, weight %				
	Fine Aggregate			Coarse Aggregate	
	Size No. 1	Size No. 2		Size No. 8	Size No. 89
		Natural	Manufactured		
12.5-mm (½-in.)	...	...	...	100	100
9.5-mm (⅜-in.)	100	...	...	85 to 100	90 to 100
4.75-mm (No. 4)	95 to 100	100	100	10 to 30	20 to 55
2.36-mm (No. 8)	80 to 100	95 to 100	95 to 100	0 to 10	5 to 30
1.18-mm (No. 16)	50 to 85	70 to 100	70 to 100	0 to 5	0 to 10
600-µm (No. 30)	25 to 60	40 to 75	40 to 75	...	0 to 5
300-µm (No. 50)	5 to 30	10 to 35	20 to 40	...	...
150-µm (No. 100)	0 to 10	2 to 15	10 to 25	...	...
75-µm (No. 200)	...	0 to 5	0 to 10	...	...

17

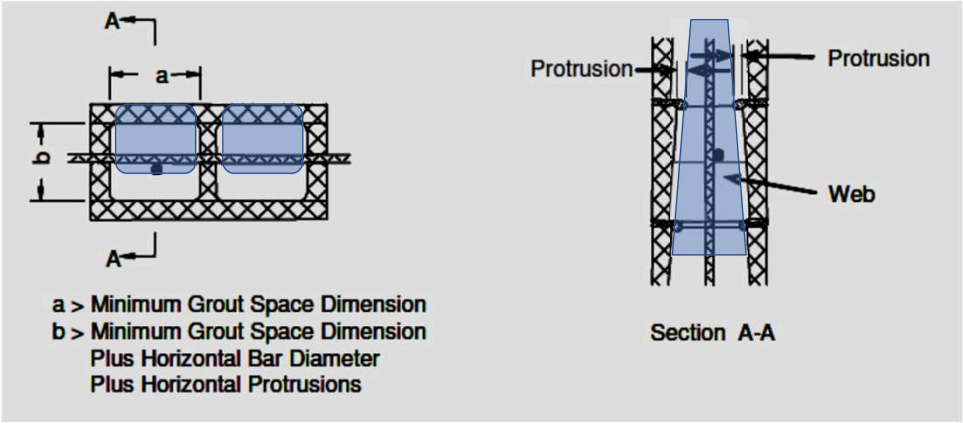
Aggregate Grading

Sieve Designation	signation, weight %	
	Coarse Aggregate	
	Size No. 8	Size No. 89
12.5-mm (½-in.)	100	100
9.5-mm (⅜-in.)	85 to 100	90 to 100
4.75-mm (No. 4)	10 to 30	20 to 55
2.36-mm (No. 8)	0 to 10	5 to 30
1.18-mm (No. 16)	0 to 5	0 to 10
600-µm (No. 30)	...	0 to 5
300-µm (No. 50)	...	...
150-µm (No. 100)	...	...
75-µm (No. 200)	...	...

18

Aggregate Grading

- Why 100% of fine/coarse particles passing $^{3}/_{16}$ in. (4.75 mm) and ½ in. (12.5 mm) sieves?
- Because grout cavities are fairly small and may contain obstructions
- Grout has to fill everywhere



19

Water

- Potable, clean
- No deleterious materials
- Sufficient water is added at mason's discretion to produce a highly fluid grout
  - Admixtures may also be used to achieve workability

Generally, same source as drinking water

Water from other sources may be acceptable

20

Water Content

- Conventional grout:
  - To provide adequate workability
  - To enable proper placement under field existing conditions, without segregation
  - Adjusted at the mason's discretion (as long as 8 to 11 in. slump maintained)
- SCG:
  - Adjustments **only as permitted** by the SCG manufacturer

21

Grout Type and Proportions

- Grout type refers to fine or coarse (aggregate)
- **Conventional grout proportions** (mix designs) are established in one of two ways:
  - By proportions (recipe)
  - By property specifications (strength), which are then converted to proportions
- **SCG proportions** are established only by the **property specification (strength)** determined by the manufacturer (and then converted to proportions)

22

Conventional Grout - by Proportion Spec (based on volume)

Type	Portland or Blended Cement	Hydrated Lime or Lime Putty	Aggregate measured in a damp, loose condition	
			Fine (sand)	Coarse (3/8 in.)
Fine	1	0 to 1/10	2 ¼ to 3 times cementitious materials	—
Coarse	1	0 to 1/10	2 ¼ to 3 times cementitious materials	1 to 2 times cementitious materials

Note: SCG mixes **cannot** be designed based on proportion specification **Must use property specification**

- Example proportions using table – fast and easy:

  Fine grout: 1 part cement, 3 parts sand (no lime)

  Coarse grout: 1 cement, 3 sand, 2 gravel (no lime)

23

Grout Proportions - by Property Spec

- Requirements for strength (ASTM C1019)
  - ≥ minimum specified compressive strength of masonry, f'_m
  - 2000 psi minimum at 28 days
- Requirement for consistency – conventional grout
  - Slump: 8 to 11 inches
- Requirements for consistency – SCG
  - Slump flow: 24 and 30 in.
  - VSI: 1 or less
- Grout mixes designed using the property specification (conventional or SCG) are converted to proportions

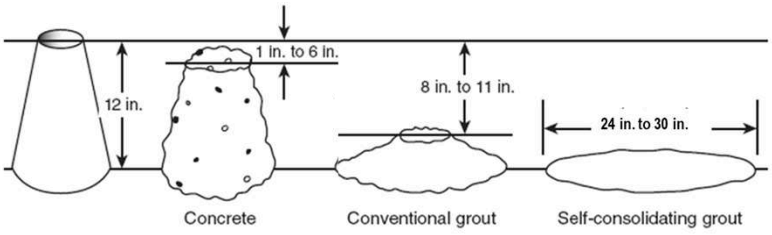
24

How much water?

- For conventional grout, enough to provide good flow and a slump of 8 to 11 in.

25

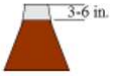
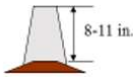
Slump of Cement-Based Materials



More about SCG consistency later

26

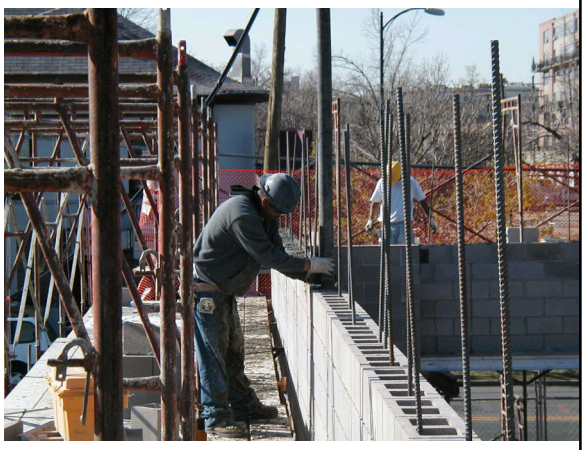
Slump of Cement Based Materials

Materials	Concrete	CMU	Mortar	Conventional Grout
	← Cement, aggregates, water, admixtures →			
Aggregate Size	< 3/4 in	< 3/8 in.	< #8 fine masonry sand	Coarse: < 3/8 in. Fine: < #4 (concrete sand)
Consistency	 Pourable, stiff	 No slump	 Sticky	 Pourable, runny
Preparation	Barrell Mixer or Truck	Mixer, vibrated into form	Paddle Mixer	Barrell Mixer or Truck

27

Manufacturing Grout

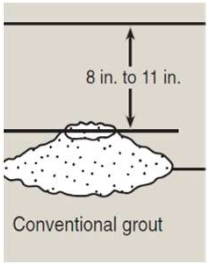
- Proportions: "controlled and accurately measured"
- Two methods:
  - Ready-mix (delivery)
  - Site mixed
- Use within 1½ hours after initial water introduction
  - For ready-mixed grout, time limit is waived as long as it meets specified slump
  - Time limit may be too long in hot weather, too restrictive in cooler weather
  - Stable, reasonable temperature (likely not yet reached initial set)



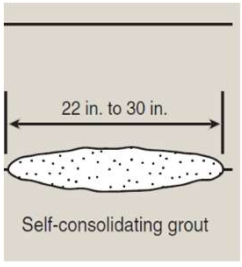
28

Measurement and Production for Ready-Mixed Grout

- Conventional grout
  - Grout arrives in ready-mixed condition
  - Slump is adjusted as necessary and remixed for at least 1 minute



- SCG
  - Grout arrives in ready-mixed condition
  - Addition of water is permitted **ONLY** in accordance with the SCG manufacturer's recommendations



29

Measurement and Production at Job Site: Conventional Grout

- Three options:
  1. Mix individual materials stored at site in mechanical mixer, 5 minutes minimum
  2. Mix individual materials transported to site with continuous volumetric proportioning equipment (auger of appropriate length)
  3. Mix factory preblended materials in mechanical mixer or with continuous mixer per manufacturer instructions

30

Measurement and Production at Job Site: Self-consolidating grout

- Two options:
  1. Mix individual materials that are part of the SCG manufacturer's system, transported to site, with continuous volumetric proportioning equipment (auger of appropriate length) per manufacturer instructions
  2. Mix factory preblended materials in mechanical mixer per manufacturer instructions

Not permitted to mix individual materials stored at site

31

Placing Grout

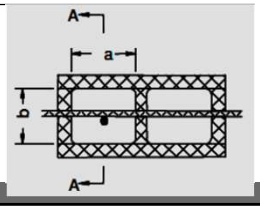
- Placed by pump or bucket with hose

32

Grout Construction Space Requirements

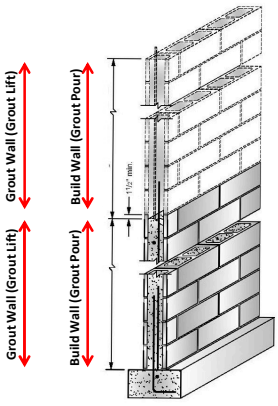
Grout type[1]	Maximum grout pour height, ft (m)	Minimum width of grout space,[2,3] in. (mm)	Minimum grout space dimensions for grouting cells of hollow units,[3,4] in. x in. (mm x mm)
Fine	1 (0.30)	3/4 (19.1)	1 1/2 x 2 (38.1 x 50.8)
Fine	5.33 (1.63)	2 (50.8)	2 x 3 (50.8 x 76.2)
Fine	12.67 (3.86)	2 1/2 (63.5)	2 1/2 x 3 (63.5 x 76.2)
Fine	24 (7.32)	3 (76.2)	3 x 3 (76.2 x 76.2)
Coarse	1 (0.30)	1 1/2 (38.1)	1 1/2 x 3 (38.1 x 76.2)
Coarse	5.33 (1.63)	2 (50.8)	2 1/2 x 3 (63.5 x 76.2)
Coarse	12.67 (3.86)	2 1/2 (63.5)	3 x 3 (76.2 x 76.2)
Coarse	24 (7.32)	3 (76.2)	3 x 4 (76 .2x 102)

Pay attention to footnotes in the specification. Horizontal steel must be considered as it reduces the grout space

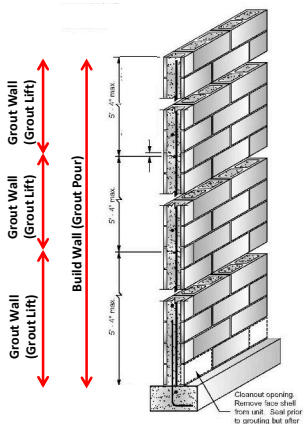


33

Grout Pour vs. Grout Lift



Low Lift Grouting



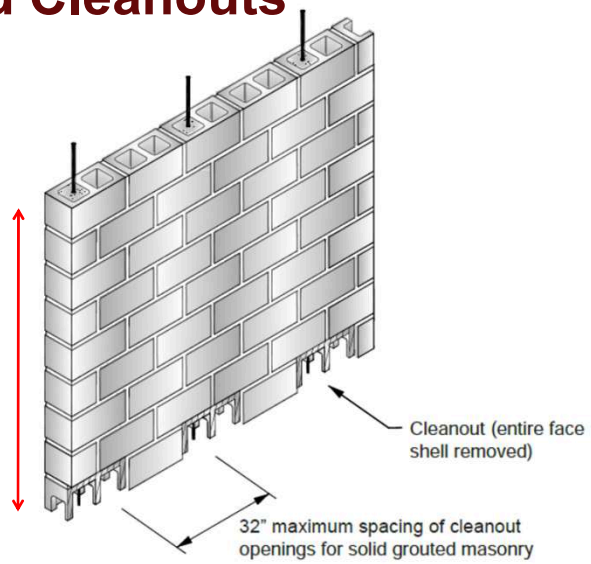
High Lift Grouting

34

Grout Pour Height and Cleanouts

If grout pour height > 5 ft 4 in.

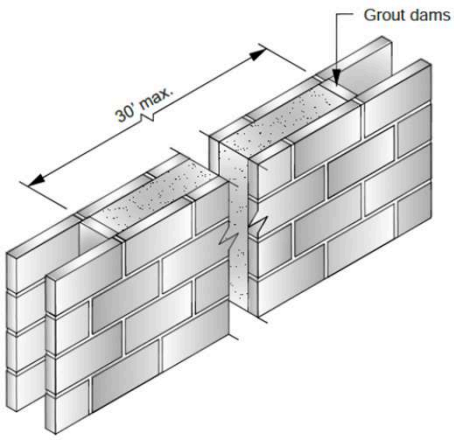
- Cleanouts:
- Are required
- Have maximum spacing = 32 in.



35

Special Considerations: Grout Barriers

- To prevent grout segregation in multiwythe grouted masonry:
  - Vertical barriers of masonry should be built across the grout space the entire height of the grout pour
  - Should be spaced not more than 30 feet (9.1 m) horizontally.
  - The grouting of any section of wall between barriers should be completed in one day with no interruption longer than one hour.



36

Consolidation of Conventional Grout

Pour height	Consolidation technique
Less than 12 in.	Mechanical vibration or puddling
12 in. or greater	Mechanical vibration Reconsolidate after initial water loss and settlement
Any height - alternate method	If a demonstration panel is shown to give adequate consolidation, limits don't apply

37

Mechanical Vibrator for Conventional Grouting

38

Self-Consolidating Grout, SCG

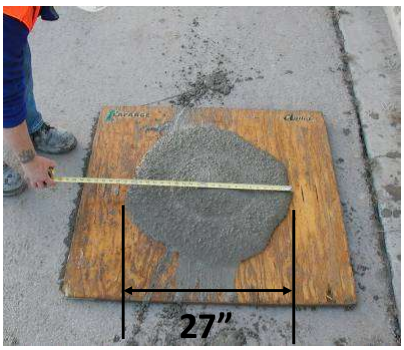
- Similar technology to self-consolidating concrete, "SCC"
- Very fluid for good filling ability
  - Demonstrate acceptability by slump flow, not slump
- Usually does not require consolidation or reconsolidation

39

Self-Consolidating Grout, SCG

40

Self-Consolidating Grout



Video clip

Consolidation typically not required, but may be permitted

41

Testing Grout

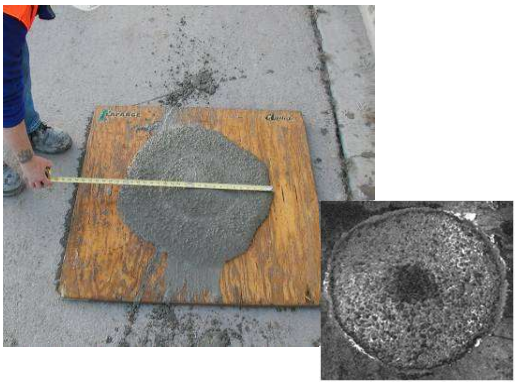
- ASTM C1019 ─ Test Method for Sampling and Testing Grout
  - Temperature
  - Slump
  - Compressive strength, 2000 psi min. or *f’m*
- ASTM C143 ─ Test Method for Slump of Hydraulic Cement Concrete
  - 8-in. to 11-in. slump required
- ASTM C1611 ─ Test Method for Slump Flow of Self-Consolidating Concrete
  - VSI ≤1 and slump flow of 24 in. to 30 in.

42

Testing Grout

Conventional grout
Slump

Self-consolidating grout
Slump Flow &
Visual Stability Index (VSI)



43

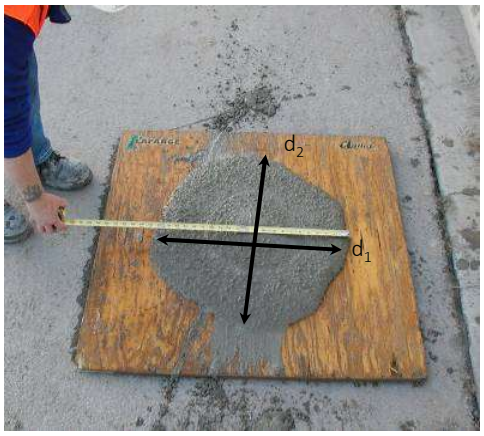
Testing SCG: Slump Flow

- Fill in one lift
- No rodding

Procedure A Procedure B

44

Testing SCG: Slump Flow



- Measured in two directions, the widest part and at an approximate right angle to that
- Slump flow is the average diameter of the pat

$$= (d_1 + d_2)/2$$

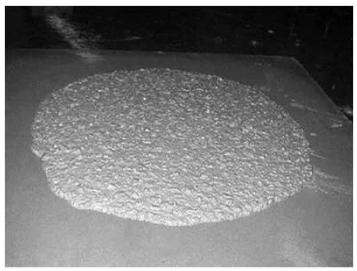
- Required to be 24 to 30 in.

45

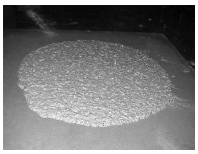
Testing SCG: VSI

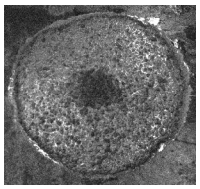
TABLE X1.1 Visual Stability Index Values

	VSI Value	Criteria
✓	0 = Highly Stable	No evidence of segregation or bleeding.
✓	1 = Stable	No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.
X	2 = Unstable	A slight mortar halo ≤ 10 mm [≤ 0.5 in.] and/or aggregate pile in the of the concrete mass.
X	3 = Highly Unstable	Clearly segregating by evidence of a large mortar halo > 10 mm [> 0.5 in.] and/or a large aggregate pile in the center of the concrete mass.



Video clip

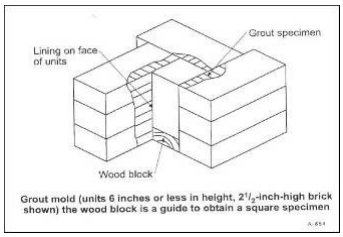


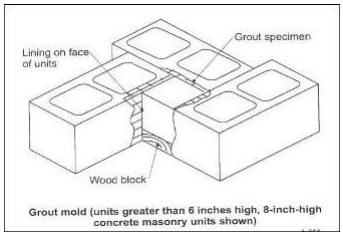
- Visual examination is a qualitative assessment
- Images are, left to right: VSI of 0, 1, 2, & 3
- Images courtesy of ASTM

46

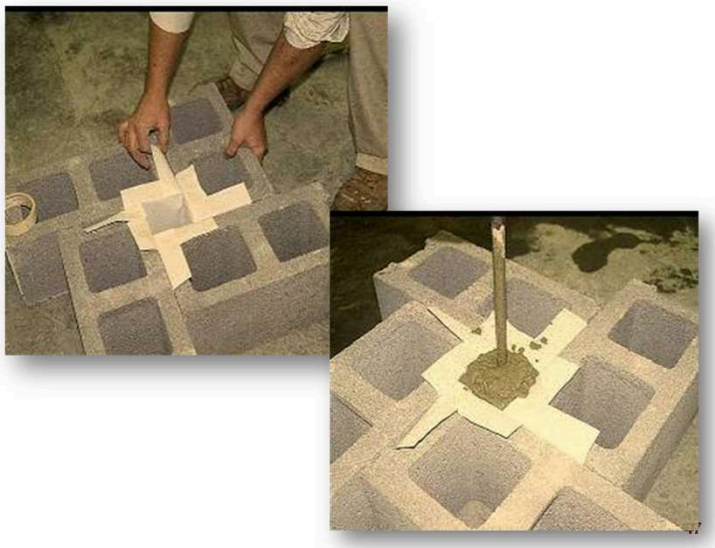
Grout Compressive Strength Specimens



Grout mold (units 6 inches or less in height, $2^{1}/_{4}$-inch-high brick shown) the wood block is a guide to obtain a square specimen



Grout mold (units greater than 6 inches high, 8-inch-high concrete masonry units shown)



Grout Compressive Strength Specimens

- Prisms represent grout placed in masonry construction
- Nominally square, 3 to 3.75 in. wide, height at least twice the width
- Initially stored at site, then transported to lab
- Cured first, then tested, usually at 28 days

- Why 28 days? This is a typical test age for concrete materials– cement gains about ¾ of its "ultimate" strength at this point

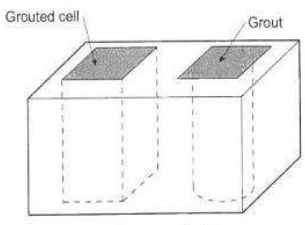
48

Testing Grout Specimens

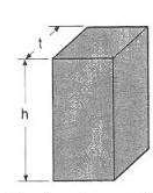
49

Alternate Grout Specimens

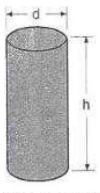
- ASTM C1019, Note 7
  - Other methods have been employed but are not covered by this test method.
  - Limit comparisons of test results to a single shape and method.



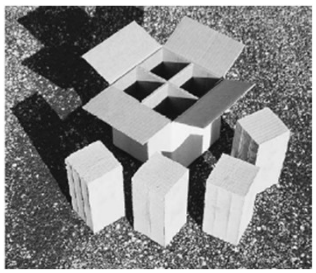
CMU with grouted cells



Grout sample saw cut from grouted cell, h/t = 2



Grout sample cored from grouted cell, h/d = 2



50

Grout for Masonry Construction

- Grout for masonry construction is made from the same materials as concrete, but it is not concrete
- Grout has to be much more fluid to fill masonry cavities
  - SCGs offer an alternative to conventional grout for ease of placement
- Two options for specifying: proportion and property
- Two types: coarse and fine
- Grout often contains high volumes of SCMs, increasing the sustainability of masonry construction

51

This concludes The American Institute of Architects Continuing Education Systems Course

THE MASONRY SOCIETY

The Masonry Society

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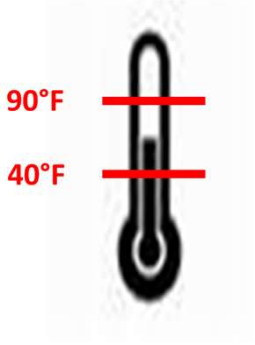
Hot & Cold Weather

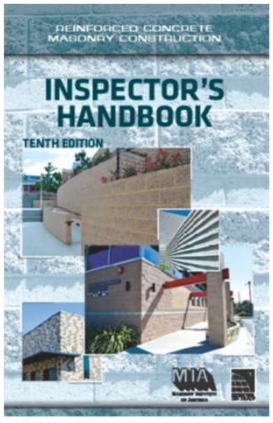
- "Normal" conditions – 40°F to 90°F
- Hot weather - above 100°F (or 90°F with an 8 mph)
- Cold weather – below 40°F
- In hot or cold weather, building new masonry may require special precautions during:
  - Preparation
  - Construction
  - Protection (immediately following construction)
- TMS 602 contains all the information you need



53

Hot and Cold Weather Construction Requirements

- What effect does weather have on masonry construction?
- Before, during, immediately after?
- Mortar and grout
  - Affects set time
  - Affects early age strength
  - Water demand
- Units
  - Affects absorption
  - Affects shrinkage
  - Affects unit placement



54

Cold Weather Grouting Tables

Grouting the Units	*Temperature Range ºF*			
	40º to 32º	32º to 25º	25º to 20º	20º and below
Heat aggregates *and* mixing water for grout 70ºF to 120ºF. Grout to be at least 70ºF at time of placement.		×	×	×
Heat masonry units to 40ºF minimum			×	×
For grouted masonry, protect for 48 hours with insulating blankets*			×	×
For grouted masonry, provide enclosure & auxiliary heat or equal to keep temperature above freezing for 48 hours*				×
*May reduce to 24 hours if only Type III Portland cement is used in grout.				

55