Grouting & Reinforced Masonry Construction

International Masonry Institute
Professional Education Programs
Version 06.1.03

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The IMI website has a wealth of great information. Special programs, training and education opportunities and features like the detailing series are all available on the website.

OUTLINE

Topical Outline

Chapter 1

Fundamentals of Structural Masonry Buildings

TOPICAL OUTLINE

What do we mean – "Structural Masonry"

- Using the masonry for the structural support of the building – not just as veneer.
- Typically the most efficient structural masonry building system is reinforced with rebar and grouted.

TOPICAL OUTLINE

Why Structural Masonry

- Versatile structural system
- Fast, efficient & economical
- Masonry may be on the project already – use it structurally!

TOPICAL OUTLINE

Why Structural Masonry

- Finish trade – so tighter tolerances held
- No lead time for production, review and approval of shop drawings
- Adapts easily to field changes –

"with masonry you just pick up the phone and the change can be done"

TOPICAL OUTLINE

Why Structural Masonry

- Local materials, local employment
- Using material efficiently – one material for structure, finish, fire resistance, blast resistance, acoustics and more…
- Masonry is "Green"
- And it looks good too!

TOPICAL OUTLINE

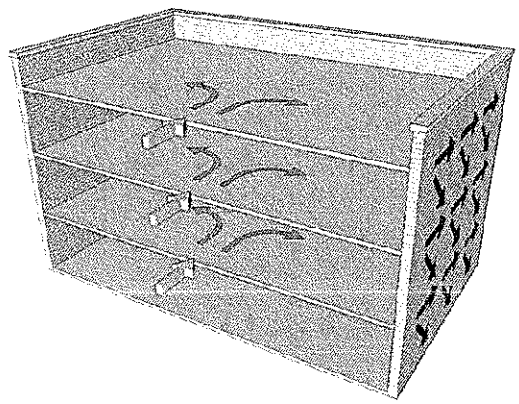
Fundamentals of Structural Masonry Buildings

Masonry Wall Behavior

TOPICAL OUTLINE

Building Load Path

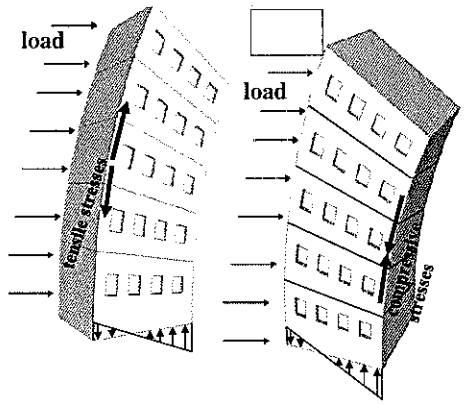
A building system must transfer loads through floors, walls and/or frames to the foundation



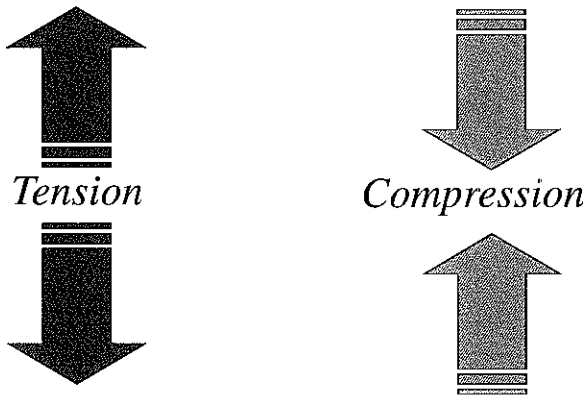
TOPICAL OUTLINE

Building Load Path

As these loads travel through the building they may create tension and compression in the masonry walls.



TOPICAL OUTLINE



TOPICAL OUTLINE

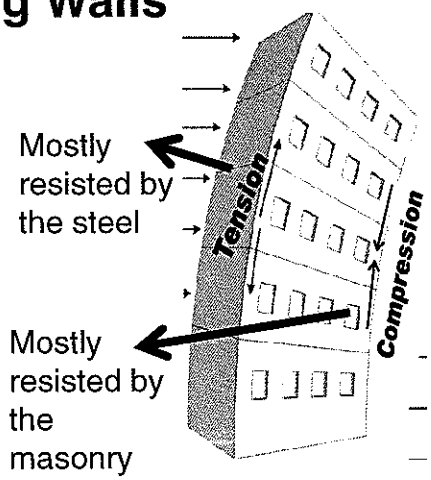
Masonry Loadbearing Walls

- Masonry is excellent at resisting compression.
- But masonry is not great at resisting tension, but reinforcing steel is.
- We reinforce the masonry with steel to resist the tension and use the masonry to resist the compression.

TOPICAL OUTLINE

Masonry Loadbearing Walls

By placing reinforcing steel in the masonry cells and grouting it in place, we create a wall that handles both the tension & compression created as the building resists loads.



TOPICAL OUTLINE

Fundamentals of Structural Masonry Buildings

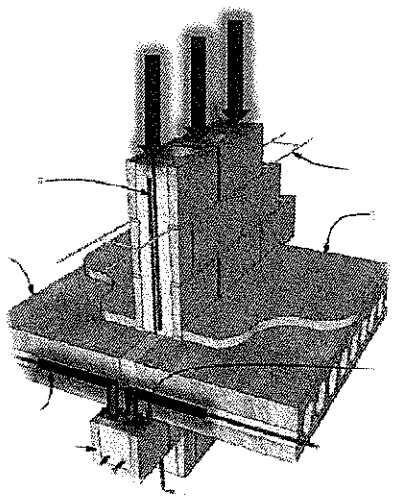
Loads –

Where does the tension and the compression come from?

TOPICAL OUTLINE

Vertical Loads

Vertical load (like load from roof or floor framing into the masonry wall) and gravity load (self-weight of the wall) are the ones most commonly thought of as being carried by masonry walls.

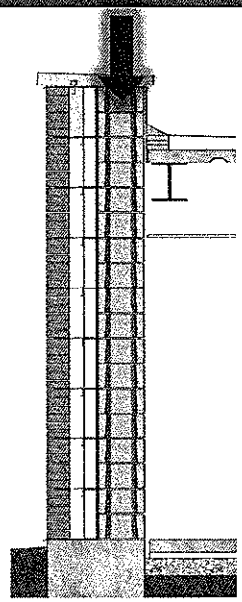


TOPICAL OUTLINE

Vertical Loads

Vertical loads, when applied **AXIALLY** *(at the center of the loadbearing wall),* tend to produce **COMPRESSION** in the wall.

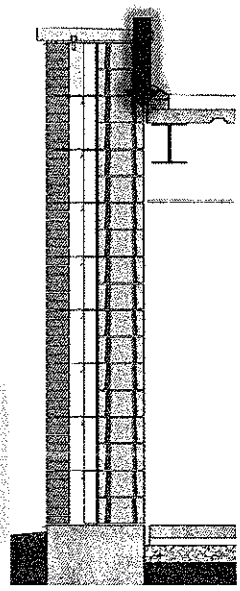
Masonry is very good at handling compression.

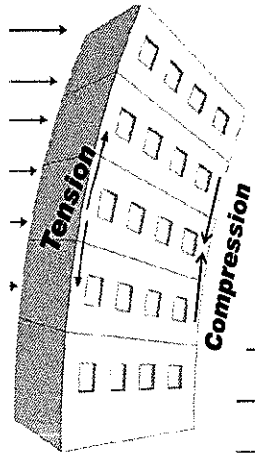


Vertical Loads

Vertical loads, when applied **ECCENTRICALLY** *(off-center),* can produce **TENSION** in the wall perhaps in addition to Compression.

Masonry is not too good at handling tension.





Horizontal Loads – Wind

- In addition to vertical loads, wind can impart very significant load on building components.
- Although we usually think of wind loads as horizontal forces created by air blowing against the building, there is also suction and uplift loads created by wind.
- The next slide illustrates the effects wind can cause on an unreinforced masonry wall

TOPICAL OUTLINE

Horizontal Loads - Wind

- If we add reinforcing bars and grout to the wall it gains the tensile strength needed to resist the wind load.
- Historic weather data is used to determine design wind loads for various geographic areas. Those design wind load conditions are then used to develop building code requirements that result in required wall size and reinforcement.

TOPICAL OUTLINE

Horizontal Loads - Wind

- In coastal areas where hurricanes develop extreme wind loads, masonry walls require considerable amounts of reinforcement.
- In the past few years design wind loads throughout the US have been reevaluated typically resulting in greater amounts of reinforcement and specific high wind detailing.
- The next slide illustrates the effect of adding reinforcing bars & grout to our unreinforced wall.

TOPICAL OUTLINE

Horizontal Loads – Wind Suction

- Wind suction loads are developed on the down wind side of the building.
- Suction loads are caused by the development of an area of low pressure near the wall as the wind blows around the building.
- This is the same physics principle that causes lift under an airplane wing.

TOPICAL OUTLINE

Horizontal Loads – Wind Suction

- Surprisingly, wind suction loads can exceed the wind pressure load on the windward side of the building, and thus become the critical design load case.
- Wind suction loads can be especially significant on masonry infill or non-bearing wall masonry where there is little vertical load to help resist the horizontal loads.
- The next illustration will show the effect of wind suction.

TOPICAL OUTLINE

Horizontal Loads - Seismic

- Seismic loads are horizontal loads that are developed by earthquakes.
- Seismic Design Categories are spelled out in the building codes. They are a combination of seismic risk and specific soil characteristics and can have very significant effects on masonry design.
- During an earthquake energy typically flows away from the epicenter in a sine wave pattern.

TOPICAL OUTLINE

Horizontal Loads - Seismic

- At the peak of the pattern, the seismic loads push foundations away from the epicenter and at the trough they relax back toward their original position.
- As the foundations move back and forth the top of the wall tries to catch up. The result is a sudden swaying and shifting of the building.
- Without enough reinforcement the wall will fail as shown in the next slide.

TOPICAL OUTLINE

Horizontal Loads – Seismic

- There are major seismic areas all along the west coast up through Alaska and in other areas like Tennessee, St. Louis, Charleston however any area of the USA can experience earthquakes.
- In higher seismic areas, reinforcement needed to counter seismic loads will usually determine the amount of reinforcing bars and grout to be used.
- The next slide shows a masonry wall reinforced to resist a seismic load.

TOPICAL OUTLINE

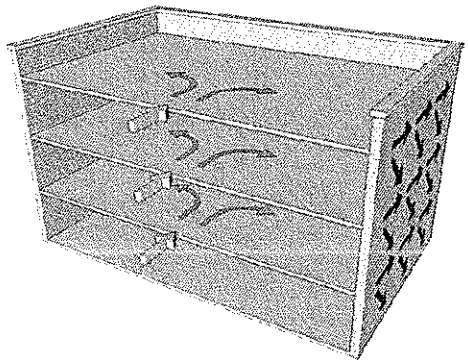
Fundamentals of Structural Masonry Buildings

So How Do Masonry Walls Resist Loads?

TOPICAL OUTLINE

Remember Load Path

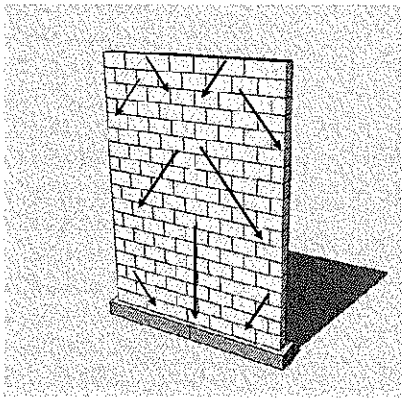
Remember that in a masonry building all loads must transfer through the floors and roof to the walls and into the foundations – we call that the load path.



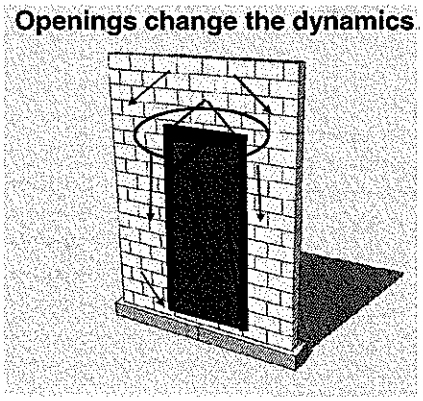
TOPICAL OUTLINE

Typical Block Wall

In masonry, the load path is typically at 45 degrees. This can create "arching action" (a triangular distribution of load) over openings.



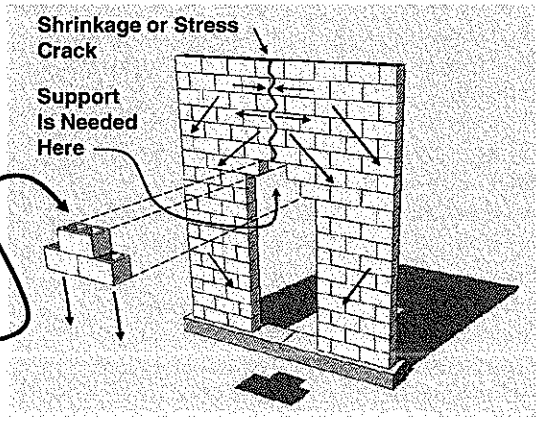
Openings change the dynamics.



TOPICAL OUTLINE

Un-Reinforced Block Wall & Doorway

Openings change the dynamics.



Without a lintel, these block are unsupported.... The wall would eventually fail.

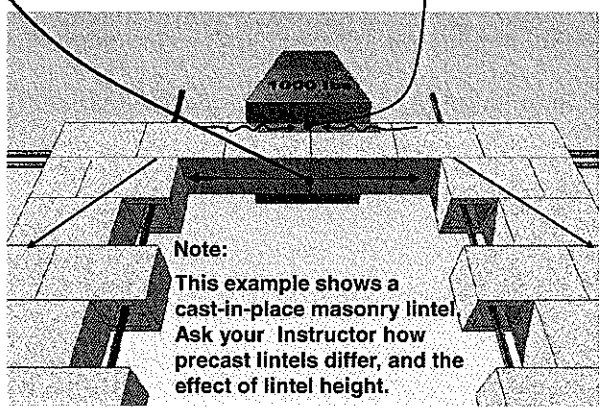
TOPICAL OUTLINE

Structural Lintels & Beams

- Structural lintels and beams support loads over openings in walls.
- They have tensile loads along the bottom and compressive loads along the top.

Reinforcing steel provides tensile strength and the masonry units provide compressive strength.

That is why reinforcing bars are found near the bottom of the lintel.



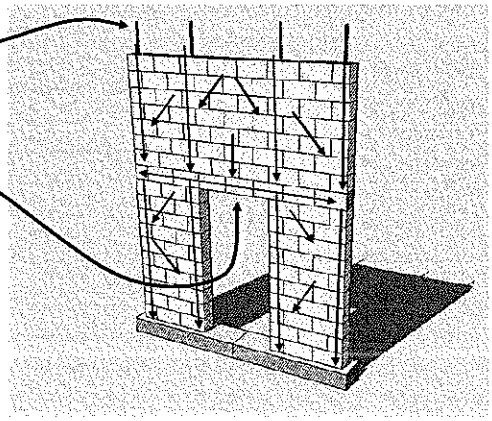
Note:
This example shows a cast-in-place masonry lintel. Ask your Instructor how precast lintels differ, and the effect of lintel height.

TOPICAL OUTLINE

Reinforced Block Wall & Doorway

Load bearing capacity is enhanced by the use of rebar & grout.

With the addition of a reinforced CMU lintel, the wall opening is now structurally sound and load is distributed to the foundation.



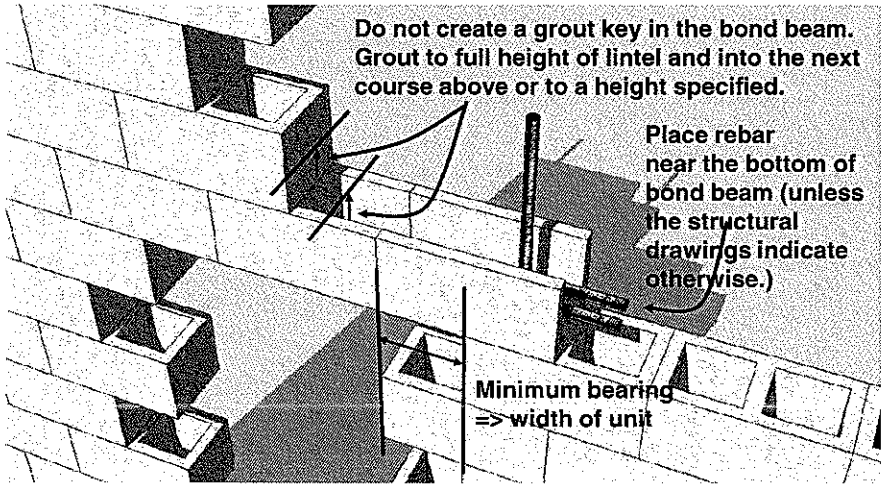
TOPICAL OUTLINE

Structural Lintels/Beams

- Structural lintels and beams are detailed by the engineer to resist specific forces.
- In order to function properly the rebar must be placed as indicated in the details.
- The entire lintel/beam should be grouted in a single lift to ensure it will function as a monolithic structural element.

TOPICAL OUTLINE

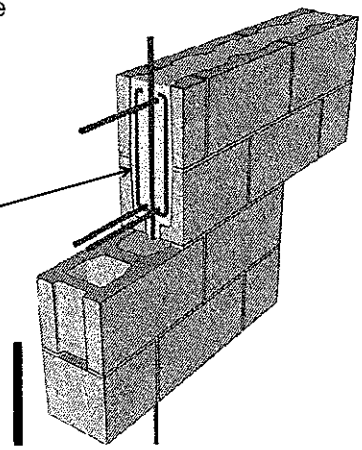
Proper Lintel/Beam Construction



TOPICAL OUTLINE

Proper Lintel/Beam Construction

- While often lintels or beams are a single course, there are also times when the engineer will specify multi-course lintels or beams.
- Multi-course lintels/beams may have horizontal rebar in several locations such as near the bottom and also near the top.
- In addition, stirrups - vertical bars (straight or bent), may be required.
- All courses of the lintel/beam should be grouted in a single lift to ensure it will function as a monolithic structural element.



TOPICAL OUTLINE

Fundamentals of Structural Masonry Walls

Other reasons to reinforce and grout masonry walls

TOPICAL OUTLINE

Fire Resistance

- Architects are expected to design buildings that are safe in the event of a fire.
- One way to do that is to design buildings constructed from materials that don't burn. Like masonry!
- The fire resistance of masonry can be improved by adding reinforcing bars & grout.
- Eventually unreinforced masonry will fail.

TOPICAL OUTLINE

Fire Resistance

- Fire resistance in masonry is measured in 'equivalent thickness' – a combination of the unit and the grout.
- When masonry is subjected to the ASTM E119 fire test, it passes much more easily than most other systems.
- Still, the addition of reinforcing bars & grout can add more fire resistance rating to the same masonry wall and may increase its ability to remain structurally sound in a fire.

TOPICAL OUTLINE

Sound Resistance

- Resistance to sound transmission is referred to as the Sound Transmission Coefficient or STC value.
- This is important for applications such as sound barrier walls along highways, dividing walls in apartment buildings and hotels or in auditorium design.
- Adding more grout adds density and increases the STC value of the wall.

TOPICAL OUTLINE

Chapter 2

Where do Reinforcement & Grouting Requirements *("the rules")* come from?

Building Codes & Standards

TOPICAL OUTLINE

A few terms you need to know…

MSJC - Masonry Standards Joint Committee

TMS 402/ACI 530/ASCE5 - *"Code"*

TMS 602/ACI530.1/ASCE6 - *"Specification"*

ICC - International Code Council

IBC - International Building Code

ASTM - ASTM International produces standards for masonry and other materials, and systems

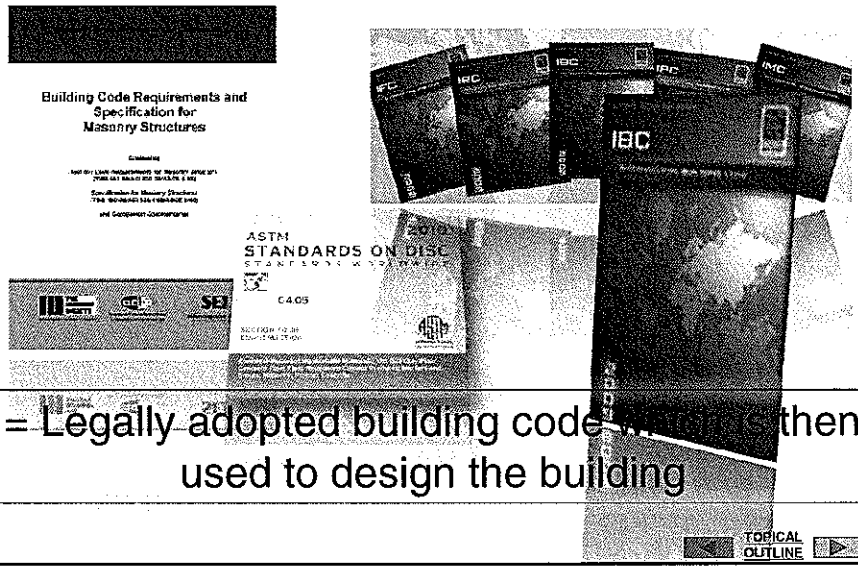
TOPICAL OUTLINE

Where do reinforcement & grouting requirements come from?

- Building Code Requirements
  - "MSJC" - TMS 402 & TMS 602
  - "IBC" - International Building Code
- ASTM Standards
- Project Documents – Drawings & Specifications

TOPICAL OUTLINE

How do they relate?



= Legally adopted building code which is then used to design the building

TOPICAL OUTLINE

Where do

Reinforcement & Grouting

Requirements come from?

Building Codes

TOPICAL OUTLINE

Building Codes Requirements – "MSJC"

- A group of industry experts, including IMI, formed a committee to develop a standard code and specification for masonry, the TMS 402 Code & TMS 602 specification.
- This group is referred to as the Masonry Standards Joint Committee or MSJC
- About every 3 years they produce an updated version of the code.

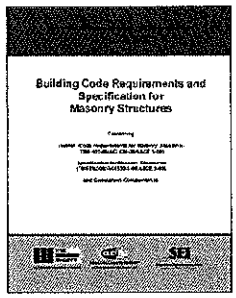
TOPICAL OUTLINE

The MSJC Documents

TMS 402-08 /ACI 530-08 /ASCE 5-08
Building Code Requirements for Masonry Structures

TMS 602-08 /ACI 530.1-08/ASCE 6-08
Specification for Masonry Structures

Commentary for each
Non-mandatory



TOPICAL OUTLINE

TMS 402 Building Code Requirements for Masonry Structures and the accompanying commentary is mostly for structural engineers and contains the design criteria, formula, reference charts and similar information necessary for engineers to determine how to engineer a masonry building.

TOPICAL OUTLINE

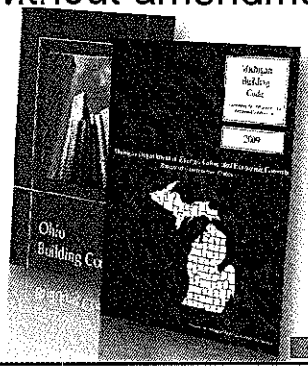
TMS 602 Specification for Masonry Structures and its accompanying commentary contains minimum standards required to be specified for a structure to meet the TMS 402 Code.

- Project specifications may add to the TMS 602 requirements but it may not reduce or eliminate them.
- It outlines the minimum requirements by which a masonry structure is to be built.
- The specification will also contain the inspection requirements.

TOPICAL OUTLINE

The TMS 402 Code is then incorporated into the next version of the building codes, such as the International Building Code or IBC.

These, in turn, are adapted by states or local jurisdictions with or without amendments.



TOPICAL OUTLINE

IBC

- IBC Chapter 21 contains both Design and Construction provisions
- Largely refers to MSJC Code with some exceptions

MSJC

- MSJC Code contains primarily structural design provisions but also a few construction requirements – Designer oriented
- Construction provisions are primarily found in the MSJC Specification – Contractor & Inspector oriented

TOPICAL OUTLINE

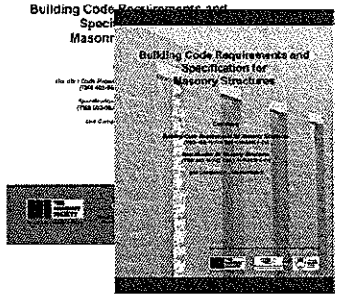
Important points to remember about codes.

- The MSJC is mostly a structural code, and is mostly for commercial applications
- The TMS 602 specifications contain mostly contractor and inspector information
- The MSJC is adopted by the IBC or your local state building code which may modify the IBC and/or MSJC provisions
- The IBC or state code will address additional requirements, such as flashing

TOPICAL OUTLINE

IMI Works For You

IMI is a voting member of the MSJC as well as participating on several code committees.
In most cases IMI is the only voice representing the craftworker.



OUTLINE

Where do

Reinforcement & Grouting

Requirements come from?

ASTM Standards

TOPICAL OUTLINE

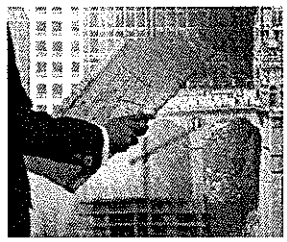
Who is ASTM?

- ASTM International is the acronym for the American Society for Testing and Materials.
- They are the largest voluntary standards development organization in the world overseeing about 12,000 standards.
- For each standard there is a committee responsible for its development and regular updating.

TOPICAL OUTLINE

IMI Works For You

IMI has members in seats on all ASTM Standards Committees that are important to masonry construction. We work to represent your point of view and to ensure masonry remains competitive into the future.



OUTLINE

ASTM C 404 – 11 is the standard Specification of Aggregates for Masonry Grout.

- General Characteristics
  - Aggregates shall consist of:
    - Natural sands
    - Manufactured sands
    - Alone or in combination with coarse aggregate

TOPICAL OUTLINE

ASTM C 404 – 11

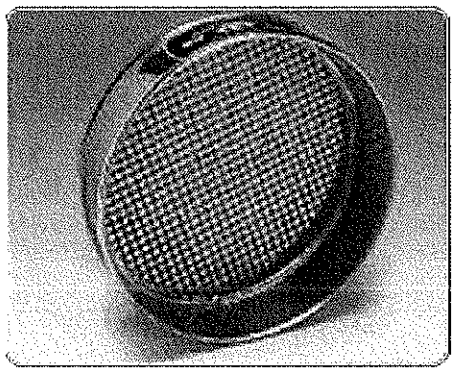
Grading

- 100% of fine aggregate shall pass through a 3/8 inch sieve.
- No more than 5% shall pass through a #200 sieve (finer than talcum powder).
- 100% of coarse aggregate shall pass through a 1/2 inch sieve.
- No more than 5% shall pass through a #30 sieve.

TOPICAL OUTLINE

Sieves are sized by dimensions of the openings created by the wires running across the pans.

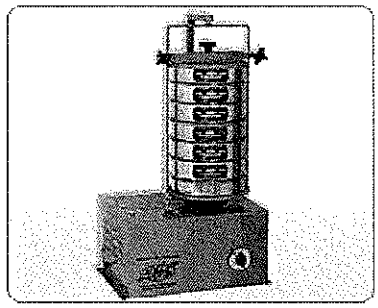
The larger the opening the larger the material that will drop through.



TOPICAL OUTLINE

To determine the ratio of sizes, a sample is taken, dried & weighed. Sieves are stacked with the largest on top and a collection pan at the bottom.

The sample is poured into the top sieve and the entire stack is shaken like a paint can at your local hardware store.

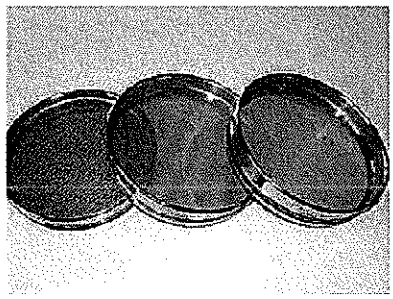


TOPICAL OUTLINE

After a prescribed amount of shaking the contents of each sieve is weighed. The individual weights are placed on a chart and compared to the sample weight to determine the ratio of that size aggregate to the whole.

C 404 Fine Aggregates require the following sieves:

4
8
16
30
50
100
200



TOPICAL OUTLINE

ASTM C 404 – 11

Sand (fine aggregates) is graded by size.

The following chart is from ASTM C- 404-11

Sieve Size	Percent Passing	
	Natural	Manufactured
No. 4	100 %	100 %
No. 8	95 - 100	95 - 100
No. 16	70 - 100	70 - 100
No. 30	40 - 75	40 - 75
No. 50	10 - 35	20 - 40
No. 100	2 - 15	10 - 25
No. 200	0 - 5	0 - 10

TOPICAL OUTLINE

ASTM C 404 – 11

Gravel (coarse aggregates) is graded by size.

The following chart is from ASTM C- 404-11.

Sieve Size	Percent Passing	
	Size # 8	Size # 89
1/2 inch	100 %	100 %
3/8 inch	85 - 100	90 - 100
No. 4	10 - 30	20 - 55
No. 8	0 - 10	5 - 30
No. 16	0 - 5	0 - 10
No. 30	-	0 - 5
	-	-

TOPICAL OUTLINE

ASTM C 404 – 11

Deleterious Substances

- Applies to fine and coarse aggregates.
- No more than 1% by weight of friable particles (light enough to be airborne).
- No more than ½% by weight of lightweight particles (light enough to float).

TOPICAL OUTLINE

ASTM C 404 – 11

Organic impurities

- Fine aggregate shall be free of organic impurities.
- Small amounts of coal, lignite or similar discrete particles are permissible.
- Fine aggregate failing this requirement must be tested to be considered for use.

TOPICAL OUTLINE

ASTM C 476 – 10 is the Standard Specification for Grout for Masonry.

Scope: Covers two types of grout:

- Fine Grout
- Coarse Grout

Each type of grout is further classified as:

- Conventional Grout
- Self Consolidating Grout (SCG)

TOPICAL OUTLINE

ASTM Standards - Grout Chapter 2

ASTM C 476 – 10 is the Standard Specification for Grout for Masonry.

Grout is specified by:

- Proportions – specific volumes or weights of ingredients are blended to create a grout mix. Typically limited to standard 2000 psi grout.
- Strength (SCG is strength only) – typically used when high strength grout is specified. Specific mix designs are developed and tested to ensure compliance.

TOPICAL OUTLINE

ASTM C 476 – 10

Materials:

- Portland Cement Types I, IA, II, IIA, III, IIIA
- Blended Cements
- Quicklime & Hydrated Lime
- Coal Fly Ash or Raw Calcined Natural Pozzolan
- Granulated Blast Furnace Slag

TOPICAL OUTLINE

ASTM C 476 – 10

Materials:

- Air – Entraining Ad Mixtures – must be approved by architect / engineer.
- Water – Clean & potable
- Pumping Aids – Must be approved
- Admixtures – Must be approved
- Admixtures for SCG include high-range water reducers & viscosity modifiers

TOPICAL OUTLINE

ASTM C 476 – 10

Materials:

- Antifreeze Compounds – no antifreeze liquids, salts, or other substances shall be used to lower the freezing point.
- Store cementitious materials & aggregates in a manner to prevent deterioration or intrusion of foreign materials.

TOPICAL OUTLINE

ASTM C 476 – 10

Grout Type & Proportions:

Two Types: Fine or Coarse

- Fine grout contains only fine aggregates.
- Coarse grout contains both fine & coarse aggregates.

TOPICAL OUTLINE

ASTM C 476 – 10

- Proportions by Volume

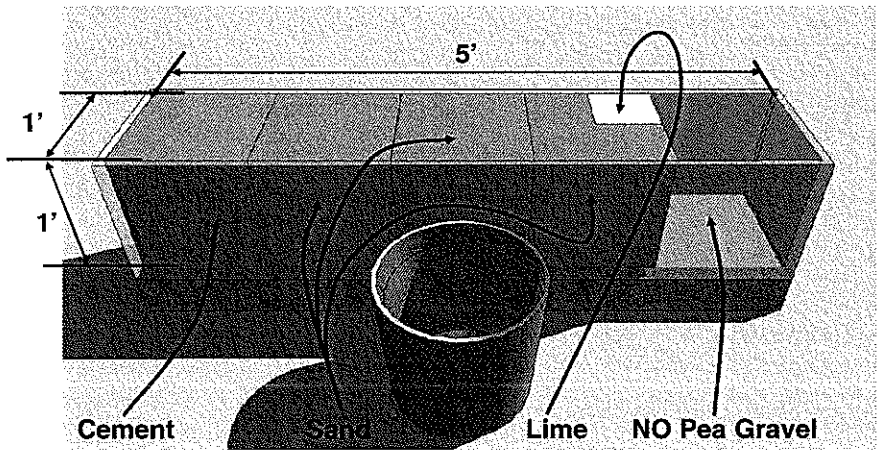
Type	Portland Cement	Lime	Aggregates * Fine	Coarse
Fine	1	1/10	2 ¼ - 3	
Coarse	1	1/10	2 ¼ - 3	1 – 2

* Measured in loose damp condition.

* Times the sum of the cementitious material.

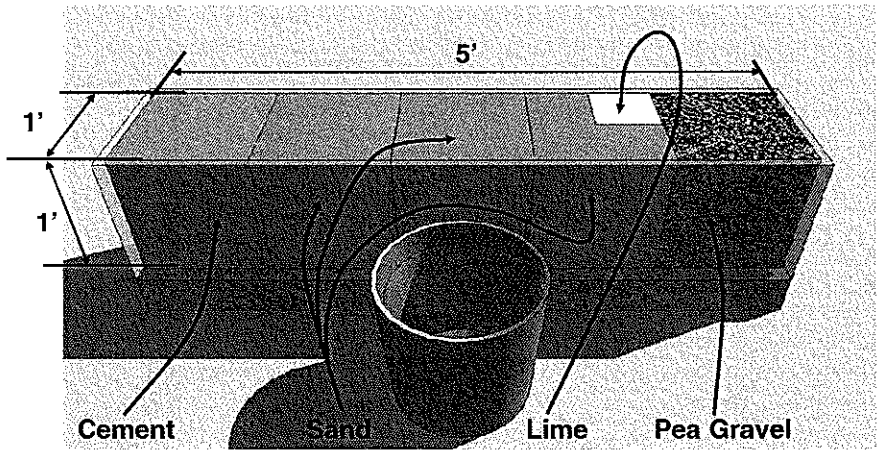
TOPICAL OUTLINE

Quantities by Volume for Fine Grout



TOPICAL OUTLINE

Quantities by Volume for Coarse Grout



Cement	Sand	Lime	Pea Gravel
1	2 ¼ - 3	1/10	1 - 2

TOPICAL OUTLINE

ASTM C 476 – 10

By Compressive Strength – Conventional Grout

- Strength established by a 28 day compressive strength test. (ASTM C 1019)
- Conventional grout shall be mixed to a slump of 8 inches to 11 inches.
- Must have a minimum strength of 2000 psi at 28 days.

TOPICAL OUTLINE

ASTM C 476 – 10

By Compressive Strength - SCG

- Established by 28 day test
- Shall have a slump flow of 24" to 30" (ASTM 1611).
- Shall have a Visual Stability Index (VSI) not greater than 1
- Must have a minimum strength of 2000 psi at 28 days.

TOPICAL OUTLINE

ASTM C 476 – 10

Measurement & Production Conventional Grout

- Proportions may be converted to weight batches by using charts provided in ASTM C 476 & ASTM C 404.

Mixed at Job Site Conventional Grout

- Mixed in a mechanical mixer for a minimum of 5 minutes.
- Use sufficient water to achieve desired slump.

TOPICAL OUTLINE

ASTM C 476 – 10

Mixed at Job Site – SCG

- Individual ingredients transported to the jobsite shall be mixed with water per manufactures recommendations
- Factory pre-blended materials shall be mixed in a mixer per manufactures recommendations to achieve desired consistency

TOPICAL OUTLINE

ASTM C 476 – 10

Mixed at Job Site - SCG

- Jobsite proportioning & mixing of individual materials not part of the manufacturer's system are not permitted

TOPICAL OUTLINE

ASTM C 476 – 10

Measurement & Production

Transit Mixed – Conventional Grout

- Factory dry blended material shall be mixed for a minimum of 5 minutes at the job site.
- Wet-mixed grout shall arrive in a ready-mixed condition.
- Adjust slump by adding water and remix for 1 minute minimum.

TOPICAL OUTLINE

ASTM C 476 – 10

Measurement & Production

Transit Mixed – SCG

- Shall arrive at site in a ready-mixed condition
- Addition of water is permitted in accordance with the manufacture's requirements

TOPICAL OUTLINE