Effective Mortar Specifications

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PCA Market Manager Buildings
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1. Name the three most common ASTM C270 mortar designations and how to select the appropriate type for your project

2. Understand the difference between proportion and property specifications

3. Name the cement standards allowed to make C270 mortars and differences between them

4. Describe the right way to assess mortar quality (and ways you should not)
Purpose of Mortar

• Holds units together
• Holds them apart
• Carries loads (compressive, flexural strength)
• Accommodates small movements
• Seals joints against air and moisture penetration
• Bonds to joint reinforcement, ties, anchors
• Creates an attractive appearance
Purpose of Grout

• Grout is used to fill masonry cavities
• Bonds units, mortar, and reinforcement into a single composite assemblage
• Is an essential component of reinforced masonry
• Is an optional component of unreinforced masonry
2.1 — Mortar materials

2.1 A. Provide mortar of the type and color specified, and conforming with ASTM C270.
ASTM C270: The Mortar Specification

• Standard Specification for Mortar for Unit Masonry

www.astm.org
C270 Contents

• Scope
  – Mortar Types
  – Methods of Specifying

• Referenced Documents

• Specification Limitations
  – Not Based on Field Tests
  – Laboratory Test Methods

• Materials

• Requirements
  – Proportion Specifications
  – Property Specifications

• Test Methods

• Construction Practices
  – Storage
  – Batching
  – Mixing
  – Tempering
  – Climatic Conditions

• Quality Assurance
C270 Mortar Types

• Cementitious materials, sand, and water
• Four types M, S, N, O (and K for tuck pointing)
• Main differences:
  – Proportions → strength and durability
  – Water content → wetter than concrete
C270 Mortar Types

Stronger mortars

Introduced as a temporary standard in 1951

weaker mortars

A-1 → M
A-2 → S
B → N
C → O
D → K
Specifying Mortar by C270

- Proportion vs. Property Requirements

**TABLE 1: Proportion Specification Requirements**

<table>
<thead>
<tr>
<th>Mortar Type</th>
<th>Cement-Lime</th>
<th>Mortar Cement</th>
<th>Masonry Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>S</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>M</td>
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Notes—Two air-entraining materials shall not be combined in mortar.

**TABLE 2: Property Specification Requirements**

<table>
<thead>
<tr>
<th>Mortar Type</th>
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<th>Average Compressive Strength at 28 days, min. psi (MPa)</th>
<th>Water Retention, min. %</th>
<th>Air Content, max. %</th>
<th>Aggregate Ratio (Measured in Damp, Loose Conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement-Lime</td>
<td>M</td>
<td>5000 (17.2)</td>
<td>75</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1900 (12.4)</td>
<td>75</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>750 (5.2)</td>
<td>75</td>
<td>12</td>
<td>14</td>
</tr>
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<td>75</td>
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</table>

- Only one shall govern
- If neither is specified, proportion specification governs
- Recipe vs. testing mortar mixes
### TABLE 1 Proportion Specification Requirements

**Note 1**—Two air-entraining materials shall not be combined in mortar.

<table>
<thead>
<tr>
<th>Mortar</th>
<th>Type</th>
<th>Proportions by Volume (Cementitious Materials)</th>
<th>Aggregate Ratio (Measured in Damp, Loose Conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cementa</td>
<td>Hydrated Lime or Lime Putty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mortar Cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Masonry Cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>Type N PCL</td>
<td></td>
<td>1 cement + 1 lime = 2 parts cementitiousous materials</td>
<td></td>
</tr>
<tr>
<td>Mortar Cement</td>
<td></td>
<td>2 parts cementitious x 2-(\frac{1}{4}) = 4-(\frac{1}{2}) parts sand up to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 parts cementitious x 3 = 6 parts sand</td>
<td></td>
</tr>
</tbody>
</table>

\(a\) Includes Specification C150, C595, and C1157 cements as described in 4.1.1.
After testing your mix design, convert back to proportions for field

**C270 — Property Specification**

### TABLE 2 Property Specification Requirements

<table>
<thead>
<tr>
<th>Mortar</th>
<th>Type</th>
<th>Average Compressive Strength at 28 days, min.</th>
<th>Water Retention, min, %</th>
<th>Air Content, max, %&lt;sup&gt;B&lt;/sup&gt;</th>
<th>Aggregate Ratio (Measured in Damp, Field Conditions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement-Lime</td>
<td>MS NO</td>
<td>350 (2.4)</td>
<td>75</td>
<td>20&lt;sup&gt;D&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Mortar Cement</td>
<td>MS NO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masonry Cement</td>
<td>MS NO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A Laboratory prepared mortar only (see Note 4).

<sup>B</sup> See Note 5.

<sup>C</sup> When structural reinforcement is incorporated in cement-lime or mortar cement mortar, the maximum air content shall be 12 %.

<sup>D</sup> When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18 %.

Up to 3-1/2 parts sand
Specifying Mortar

- Location + segment = mortar type (strength)

**TABLE X1.1 Guide for the Selection of Masonry Mortars**

<table>
<thead>
<tr>
<th>Location</th>
<th>Building Segment</th>
<th>Mortar Type</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior, above grade</td>
<td>load-bearing wall</td>
<td>N</td>
<td>S or M</td>
</tr>
<tr>
<td></td>
<td>non-load bearing wall</td>
<td>O^B</td>
<td>N or S</td>
</tr>
<tr>
<td></td>
<td>parapet wall</td>
<td>N</td>
<td>S</td>
</tr>
<tr>
<td>Exterior, at or below grade</td>
<td>foundation wall, retaining wall, manholes, sewers,</td>
<td>S^C</td>
<td>M or N^C</td>
</tr>
<tr>
<td></td>
<td>pavements, walks, and patios</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>load-bearing wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>non-bearing partitions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>tuck pointing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior or Exterior</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^A This table does not provide for many specialized mortar uses, such as chimney, reinforcing, etc.

^B Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated, not subject to high wind or other significant lateral load.

^C Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to.

- Choose proportion (default) or property
- Do we need to limit cement selection?
Learning Objectives 1 and 2

1. Name the three most common ASTM C270 mortar designations and how to select the appropriate type for your project
   1. M, S, and N
   2. Location/exposure and type of element
   3. N unless you need something else

2. Understand the difference between proportion and property specifications
   1. “Recipe” is default, otherwise testing required
C270 Mortar Ingredients

- Aggregate (sand)
- Water
- Admixtures
- Cementitious materials
4.1.2 *Aggregates*—See Specification **C144**.

X1.7.6.3 Unfortunately, aggregates are frequently selected on the basis of availability and cost rather than grading. Mortar properties are not seriously affected by some variation in grading, but quality is improved by more attention to aggregate selection. Often gradation can be easily and sometimes inex-pensively altered by adding fine or coarse sands. **Frequently the most feasible method requires proportioning the mortar mix to suit the available sand within permissible aggregate ratio tolerances, rather than requiring sand to meet a particular gradation.**
4.1.3 Water—Water shall be clean and free of amounts of oils, acids, alkalies, salts, organic materials, or other substances that are deleterious to mortar or any metal in the wall.
Admixtures in C270

- None unless specified
  - By ASTM C1384
  - By ASTM C979 (color pigments)
  - If non-C1384 or non-C979, must use property specification

- Limited calcium chloride
# Cementitious Materials in C270

## ASTM Specifications

<table>
<thead>
<tr>
<th>C270, cements</th>
<th>C270, limes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C150  portland cement</td>
<td>C5     quicklime</td>
</tr>
<tr>
<td>C595  blended cement</td>
<td>C207    hydrated lime</td>
</tr>
<tr>
<td>C1157 hydraulic cement</td>
<td>C1489   lime putty</td>
</tr>
<tr>
<td>C91   masonry cement</td>
<td></td>
</tr>
<tr>
<td>C1329 mortar cement</td>
<td></td>
</tr>
</tbody>
</table>
Portland Cement Manufacturing

Grinding into cement

4. Clinker with gypsum is ground into portland cement and...
C270 allows the following:

4.1.1.7 *Quicklime*—See Specification C5.

4.1.1.8 *Hydrated Lime*—Specification C207, Types S or SA. Types N or NA limes are permitted if shown by test or performance record to be not detrimental to the soundness of the mortar.

4.1.1.9 *Lime Putty*—See Specification C1489.

Lime is a plasticizer with portland, blended, and hydraulic cements.
3.1 Definitions:
3.1.1 masonry cement—a hydraulic cement, primarily used in masonry and plastering construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as limestone, hydrated or hydraulic lime) together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability.

C270 allows the following:

4.1.1.5 Masonry Cement—See Specification C91.
C1329 Mortar Cement

Flexural bond strength requirement makes performance similar to PCL mortars

C270 allows the following:

4.1.1.6 Mortar Cement—See Specification C1329.
Cement Specifications Have to Evolve

- For every ton of portland cement
  - About 0.9 tons of CO₂
- Manufacturers need to improve cement’s environmental footprint
- Maintain performance
Long-Term Reduction in Energy to Produce Cement in U.S.

Energy usage, million BTU/ton

Year


C150 portland cement
C595 blended cement
C1157 hydraulic cement

C150 - 5% limestone
C595 PLCs 5% - 15% limestone
C1157 40% decrease 1972-2010
potential for further decrease in 2012
## Benefits of Ground Limestone Additions to Cement

<table>
<thead>
<tr>
<th>For Users</th>
<th>For Public</th>
<th>For Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent strength and durability</td>
<td>Equivalent strength and durability</td>
<td>Less CO₂ emitted</td>
</tr>
<tr>
<td>Consistent performance</td>
<td>Less CO₂ emitted</td>
<td>Less energy required</td>
</tr>
<tr>
<td>Optimum fineness</td>
<td>Reduced use of natural resources</td>
<td>Increased capacity</td>
</tr>
<tr>
<td>Better chemical control</td>
<td>Environmentally friendlier</td>
<td>Lower clinker factor</td>
</tr>
</tbody>
</table>

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![Cement manufacturing process diagram](image-url)
C91 Masonry Cement

- Standard first appeared in early 1930s
- Currently, masonry cement used to make about 75% of all mortars
- Aspects of both performance and prescriptive specifications
Drying Shrinkage

% Shrinkage

Type N  Type S

PCL  MC

Shrinkage

Drying Shrinkage
Absorption

Absorption, gm

MC  PCL
Sulfate Resistance

Sulfate Expansion

Age, Wks
Learning Objective 3

3. Name the cement standards allowed to make C270 mortars and differences between them

1. Portland, blended, hydraulic cements (plus lime)
2. Masonry cement
3. Mortar cement

Is there any reason to limit the cement type?
Flexural bond strength is only an issue:
• for participating elements (part of the lateral force-resisting system)
• in medium to high seismic areas (SDC D, E, F)
• and only when elements are not fully grouted
C1072 Flexural Bond Strength
Factors Affecting Bond Strength

Water Content

- Cement Content
- Surface Texture
- Curing
- Air Content
- Rate of Absorption
- Disturbed Units
- Water Retentivity
- Test Procedures
- Compaction
- Elapsed Time

Flexural and compressive strengths vs. water/cement ratio
Water Penetration

- Testing shows that a 4 in. masonry wall is not a reliable barrier to a wind driven rain
- Factors that are:
  - Workmanship and design
  - Unit IRA
  - Mortar flow
  - Bond strength?
  - Extent of bond
ASTM C1714

Preblended Dry Mortar Mix for Unit Masonry

1. Scope*

   1.1 This specification covers masonry mortars whose materials and design requirements are governed by Specification C270 but are preblended dry in a factory instead of produced from individual raw materials delivered to the job-site.

9. Testing

   9.1 Testing shall be conducted in accordance with Specification C270 with the following exceptions:

   9.1.1 For mortar mixes meeting the proportion specification, testing shall be conducted in accordance with the requirements of Specification C144.
C270 Quality Assurance: 3 Criteria

1. Right materials
   - Material certificates (manufacturer, brand, type)

2. Materials meet standards
   - Material certificates or product data

3. Proper proportions
   - Observation
   - Mortar aggregate ratio
QA: Proper Proportions - Observation

- Inspect batching and mixing
- A 1 cu ft box is a simple way to check sand additions
- Observe mixing (3 to 5 minutes per C270)
- These are “periodic” observation activities
QA: Proper Proportions – Mortar-Aggregate Ratio

• A C780 test method for evaluating the proportions of fresh mortar mix
• Amount of sand relative to cementitious materials
• Best method to determine if the proper proportions were used in the field mix
What about Compressive Strength?

- C780 test method
- Molded cubes or cylinders
- Not representative of actual compressive strength of mortar in the assembly
- Not appropriate for use in predicting strength of mortar in the assembly
Why can’t C270 property requirements be applied to field mortar?

Because preparation of materials and mixed consistency are specified in C270, and are different than a field mix.

Differences:
- Oven-dry sand
- Bench-top mixer
- Water content
C270, C780, and C1586 all say the same thing about mortar strength...

Does the strength of a mortar cube represent the strength of the mortar in the wall?

**NO!**

The mortar in the wall will be much stronger than the tested strength of the cube because of …

- Smaller aspect ratio of mortar joint
- Lower water to cement ratio for mortar joint
- So why test it? We shouldn’t.
Learning Objective 4

4. Describe the right way to assess mortar quality (and ways you should not)

1. Observation of proportions, mixing
2. Mortar aggregate ratio
3. Compressive strength - not recommended
Retempering
Mortar Age, Water Content

• Use mortar within $2^{1/2}$ hours from time of first mixing
• Retemper as needed
  • Except for white and colored mortars
Cement Color and Pigment Dosage

Cement colors vary; affect pigment/dosage
Tooled and Other Joint Finishes

- Weather resistance
Good Workmanship, Cleaning