No. 1: Pozzolan-Lime Binders
A Brief Study in Compatibility
A Masonry Assembly basically consists of:

**Units**, such as...

- Natural Stone
- Cast Stone
- Brick
- Terra Cotta

**Mortar** to support, seal and cement the Masonry Units together.
Mortar consists of:

**Aggregate**, such as...
- Sand

**Binder**, such as...
- Clay
- Lime
- Hydraulic Lime
- Natural Cement
- Portland Cement

**Additives**, such as...
- Pozzolan
Principals in Repair:

• Repairs Must be Structurally, Functionally Sound
• Materials Must be Physically, Chemically Compatible
• Repairs Must be Visually Indistinct
• Repairs Must be Durable
Material Considerations:

- Use similar Masonry Units, if performed well and available
- Use similar Mortar Aggregate, if performed well and available
- Use COMPATIBLE Mortar Binders
Binder Compatibility/ Physical Performance

Durability

- A non-durable mortar or grout will result in the structural breakdown of the masonry.
Binder Compatibility/ Physical Performance

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Strength
- Too strong a mortar or grout can cause damage to the masonry units.
Binder Compatibility/ Physical Performance

**Durability**
- A non-durable mortar or grout will result in the structural breakdown of the masonry.

**Strength**
- Too strong a mortar or grout can cause damage to the masonry units.

**Breathability**
- A non-breathable mortar or grout can trap moisture within the masonry and cause internal damage.
Binder Compatibility/ Mineralogical Evolution

Historical (pre-Modern Era) Binders, available throughout history included Lime, naturally occurring Hydraulic Lime, and sometimes Clay.

Natural Cement was discovered in the Early 19th Century, ushering in the Modern Era of masonry construction.

Portland Cement, an artificial and improved substitute for Natural Cement, was invented in the late 19th Century.
Modern binders contained increasing amounts of silica.

Combined Silica (SiO₂) Content
as approximate percentages of Pure Binders by weight
Binder Compatibility/ Mineralogical Evolution

This resulted in increased Compressive Strengths,

Approximate Compressive Strengths
for Mortars of Pure Binder Plus Sand at CT

- Portland Cement (1:2)
- Natural Cement (1:2)
- Eminently Hydraulic Lime
- Moderately Hydraulic Lime
- Non-Hydraulic Lime
Binder Compatibility/ Mineralogical Evolution

...increased Tensile Strengths,

Approximate Tensile Strengths for Mortars of Pure Binder Plus Sand at CT

- Portland Cement
- Natural Cement
- Eminently Hydraulic Lime
- Moderately Hydraulic Lime
- Non-Hydraulic Lime
Binder Compatibility/ Mineralogical Evolution

... ever faster Strength Gain,

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Time

MODERN ERA

PRE-MODERN ERA

Portland Cement- Fast Cure/ High Strength
Natural Cement- Fast Cure/ Mod. Strength
Eminently Hydraulic Lime- Mod Cure/ Mod. Low Strength
Moderately Hydraulic Lime- Mod Cure/ Low Strength
Non-Hydraulic Lime- Slow Cure/ Low Strength

Curing Time
- Hydrating Cement-Based mortars cure rapidly, typically tested at 28-days
- Carbonating Lime-Based mortars cure slowly for years
Binder Compatibility / Mineralogical Evolution

...and decreased Water Vapor Permeability

Hypothetical Comparison of Water Vapor Permeability for Pure Binders Plus Sand

- Portland Cement
- Natural Cement
- Eminently Hydraulic Lime
- Moderately Hydraulic Lime
- Non-Hydraulic Lime
Binder Compatibility / Mineralogical Evolution

Natural “Air” Lime, cures through atmospheric carbonation.

- Hydrated Lime
- Atmospheric Carbon

Cured Lime

Diagram:
- Calcium carbonate, limestone, chalk, etc.
- Carbonation
- Burning
- Aggregate
- Slaking
- Quick lime
- Calcium hydroxide
- + H₂O = lime putty
Modern (Natural and Portland) Cements, cure through Hydration, which is based almost entirely on the silica based reactions.
Natural Hydraulic Lime, cures through Carbonation and Hydration because of a naturally occurring silica (clay) based pozzolan in the stone.
Binder Compatibility/ Mineralogical Evolution

Natural Hydraulic Lime is Calcium or Calcium and Magnesium combined naturally with clay which allows it to hydraulically cure.

![Calcium/Magnesium + Silicacious Clay = Natural Hydraulic Lime](image)

Pozzolonic Hydraulic Lime is Calcium or Calcium and Magnesium that is artificially mixed with a pozzolan, such as fired clay, which allows it to hydraulically cure.

![Calcium/Magnesium + Pozzolan = Pozzolanic Hydraulic Lime](image)
Natural Hydraulic Lime, cures through Carbonation and Hydration because of a naturally occurring silica (clay) based pozzolan in the stone.
An addition of Portland Cement of less than 10 percent of total binder weight is allowed under ASTM C1707, and designated as a “PHLc”.

Calcium/Magnesium Pozzolan + Portland Cement = Pozzolanic Hydraulic Lime “PHLc”
The small amount of Portland or Natural Cement added to the Hydraulic Lime will create a parallel hydration reaction that accelerates the hardening of the combined product while not significantly affecting its other properties.
Approximate Compressive Strengths for Mortars of Pure Binder Plus Sand at CT

Low to Moderate Compressive Strengths,

- Portland Cement (1:2)
- Natural Cement (1:2)
- PHLc/ Hydraulic Lime
- PHL/ Hydraulic Lime
- Non-Hydraulic Lime

PRE-MODERN ERA
Approximate Tensile Strengths
for Mortars of Pure Binder Plus Sand at CT

- Portland Cement
- Natural Cement
- PHLc/ Hydraulic Lime
- PHL/ Hydraulic Lime
- Non-Hydraulic Lime
Binder Compatibility/ Pozzolan-Lime “PHL”

Reasonable Strength Gain

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Time

- Portland Cement- Fast Cure/ High Strength
- Natural Cement- Fast Cure/ Mod. Strength
- PHLc/ Hydraulic Lime- Mod Cure/ Mod. Low Strength
- PHL/ Hydraulic Lime- Mod Cure/ Low Strength
- Non-Hydraulic Lime- Slow Cure/ Low Strength

Curing Time

- Hydrating Cement-Based mortars cure rapidly, typically tested at 28-days
- Carbonating Lime-Based mortars cure slowly for years
Binder Compatibility/ Pozzolan-Lime “PHL”

Good Water Vapor Permeability

Pre-Modern Era

Hypothetical Comparison of Water Vapor Permeability for Pure Binders Plus Sand

Portland Cement
Natural Cement
PHLc/ Hydraulic Lime
PHL/ Hydraulic Lime
Non-Hydraulic Lime
VOIDSPAN Products with PHL and PHLc Binders

#500 Series PHLc Gravity Feed Grout
This is our standard, ultra-low-shrinkage, flowable self-consolidating grout for gravity feeding of deep cracks and voids in older masonry structures.

#600 Series PHLc70 Injection Grout
This is a finer, injectable self-consolidating grout for filling narrow cracks and voids in historic masonry, and for injecting through VoidSpan Port Anchors. It can also be used as a moderate-strength adhesive for bonding stone dutchmen and broken fragments.

#100 and 200 Series PHL and PHLc Mortar Binders
These ASTM C1707-compliant binders are for the creation of historically compatible mortars under ASTM C1713. Designed to be mixed by the user with local sands (and pigments, if needed), PHL is a pozzolan-lime binder and PHLc has pozzolan, lime and less than 15% of cement. A typical mix ratio is one part binder to 2 parts sand, resulting in 28-day compressive strengths close to the desired minimum strengths of ASTM C270 Type O and Type N, respectively, with our PHL and PHLc binders.

#300 Series PHLc Fine Pointing Mortar
This is our ready-to-use mortar for the pointing of the exceptionally narrow “butter joints” that are seen in many brick buildings of the second half of the 19th century.

#700 Series PHLc70 Crack Filler
This crack filler is a unique, paste-consistency product that is designed to be used as a surface filler for cracks on vertical planes. It is provided in smaller, re-sealable containers, and can be color-matched with the addition of dry pigments in the field.
## VoidSpan Product Selection Guide

<table>
<thead>
<tr>
<th>VoidSpan</th>
<th>#100 Series PHL Mortar Binder</th>
<th>#200 Series PHLc Mortar Binder</th>
<th>#300 Series PHLc Fine Pointing Mortar</th>
<th>#400 Series PHLc70 Crack Filler</th>
<th>#500 Series PHLc Gravity Feed Grout</th>
<th>#600 Series PHLc70 Injection Grout</th>
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<tbody>
<tr>
<td>Crack Repair and Re-Bonding Separated Masonry</td>
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<tr>
<td>Surface Filling of Cracks and Crazing</td>
<td></td>
<td></td>
<td>For filling gaps between 3 mm (1/8”) and 8 mm (5/16”) wide.</td>
<td>For filling gaps up to 6 mm (1/4”) wide.</td>
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<tr>
<td>Pressure Injecting Cracks and Cavities</td>
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<td></td>
<td></td>
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<td>For use with grouting ports and VoidSpan Port Anchors</td>
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<tr>
<td>Gravity Feed Grouting of Cracks and Cavities</td>
<td></td>
<td></td>
<td></td>
<td>For filling gaps of 10 mm (3/8”) or greater. May be blended with peastone for gaps of 75 mm (3”) or greater.</td>
<td>For filling gaps of 3 mm (1/8”) to 25 mm (1”). Gaps down to 1 mm (3/64”) require special procedures.</td>
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<tr>
<td>Adhering Loose Fragments; Bonding Fitted Dutchmen</td>
<td></td>
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<td></td>
<td>For bond line widths down to 2 mm (3/32”) when mixed to a paste.</td>
<td>For bond line widths down to 1 mm (3/64”) when mixed to a paste.</td>
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# Repair Products with PHL and PHLc Binders

<table>
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<tr>
<th>VOIDSPAN PRODUCT SELECTION GUIDE</th>
<th>#100 SERIES PHL MORTAR BINDER</th>
<th>#200 SERIES PHLc MORTAR BINDER</th>
<th>#300 SERIES PHLc FINE POINTING MORTAR</th>
<th>#400 SERIES PHLc70 CRACK FILLER</th>
<th>#500 SERIES PHLc GRAVITY FEED GROUT</th>
<th>#600 SERIES PHLc70 INJECTION GROUT</th>
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<tr>
<td>REBUILDING UNIT MASONRY REPOINTING</td>
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<tr>
<td>• UNIT MASONRY RECONSTRUCTION</td>
<td></td>
<td>For most structures with hydraulic lime and low cement/high lime mortar blends.</td>
<td>For structures with less than 8 mm (5/16&quot;) mortar joint width.</td>
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<tr>
<td>• CUTTING AND POINTING</td>
<td>For pointing over lime-based bedding mortars, and for use with low strength masonry units and adobe.</td>
<td>For pointing over hydraulic lime and cement-lime bedding mortars, with moderate to high strength masonry units.</td>
<td>For pointing of joints less than 8 mm (5/16&quot;) wide (butter joints).</td>
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</tr>
<tr>
<td>• FILLING OF COLLAR JOINTS; BONDING BETWEEN RECONSTRUCTED WYTHES</td>
<td></td>
<td></td>
<td></td>
<td>For filling gaps of 10 mm (3/8&quot;) or greater. May be blended with peastone for gaps of 75 mm (3&quot;) or greater.</td>
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