NATIONAL LIME ASSOCIATION

SPECIFICATIONS FOR

lime and its uses

IN PLASTERING, STUCCO, UNIT MASONRY AND CONCRETE

November, 1966

NATIONAL LIME ASSOCIATION
4000 BRANDYWINE STREET, N.W. WASHINGTON, D.C. 20016

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FOREWORD

About Building Lime

Since history was first recorded, burned lime in hydrated forms has been employed continuously as a mortar and plastering material in every continent of the world. Many historical structures of 250 to 5,000 years old, in which lime was employed as a bonding material, are still standing today: Egyptian pyramids, the Great Wall of China, the Pantheon and Coliseum of Rome, the Alhambra of Spain, and others from antiquity. Later examples also abound in the New England states, Virginia, and other sections of Colonial America. In fact, lime was the only cementitious or binding material used in mortar until the advent of portland cement in the latter part of the 19th century.

The term "lime" is a much-abused term and is often used erroneously to connote any calcareous material, including limestone and dolomite. However, according to Webster, "lime," which comprises building lime, *can only be a burned form of lime,* derived from the calcination of limestone, a carbonate, sedimentary rock. The heat expels carbon dioxide as a gas from the stone, forming an oxide of calcium or calcium-magnesium, popularly known as quicklime, unslaked lime, or "hot" lime. However, for building purposes lime can never be utilized in this unslaked, oxide form. It first must be slaked with water, thus hydrating the oxide into a hydroxide form, known commercially as hydrated lime, slaked lime, or lime putty.

Stated chemically, the above reactions are:

*For Calcination**

Limestone (calcium carbonate) + heat (2000°F) → Quicklime (calcium oxide) + carbon dioxide

*For Hydration**

Quicklime (calcium oxide) + water → hydrated lime (calcium hydroxide)

In the latter reaction, the resulting hydrated lime may be in the form of an extremely fine, dry, fluffy, white powder, known commercially as hydrated lime or as a wet, plastic paste or putty, the difference being that more water is admixed into the latter form of hydrate. The dry, finely divided hydrate is readily converted into a putty on the addition of more water. To attain the desired plasticity with *normal* types of dry hydrate, it is necessary to soak the putty for at least 16 hours or overnight. However, *special* hydrated limes, designated by the American Society for Testing and Materials as Type S, are widely produced in the U.S. and do not require soaking. These special hydrates can be introduced as dry powders directly into the mortar mixer with the requisite amounts of sand, water, cement, or other additives and develop high plasticity immediately after adequate mixing. The other alternative is to proportion the hydrate putty from either slaked quicklime or soaked dry hydrate into the mortar mixer by the shovel-full.

Thus, structural lime is commercially supplied to the building trades in the following forms: as a packaged dry, finely divided hydrate, Types N and S (the Type S is a premium-priced quality hydrate); as packaged pulverized quicklime, which is slaked into a putty at the job site; as truckloads or drums of lime putty or ready-mixed sanded mortar from central-mixing plants; and as an ingredient in *some* brands of prepared proprietary (or patent) one-bag masonry cements (sanded or unsanded).

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*Approximately these same reactions occur with dolomitic limestone and quicklime ($CaCO_3 \cdot MgCO_3$ and $CaO \cdot MgO$, respectively).

In the U.S. and Canada, there are two basic types of relatively pure limes used for building: *high calcium* and *dolomitic* (high magnesium). Both types are used successfully and are recognized in the ASTM specifications for structural lime. Hydrated limes are either designated as "mason's lime" or "finishing lime," primarily intended for either masonry mortar or plastering purposes, respectively. As a generalization the hydrated limes used for plastering are more highly refined than those used for mortar, although some mason's limes are equally refined and can be used interchangeably. Invariably, "finishing lime" constitutes an excellent "mason's lime," but frequently a good mason's hydrate does not qualify as a satisfactory finishing lime. Lime putty from slaked quicklime is employed interchangeably for masonry and plaster.

Lime Properties—Lime is primarily employed because of its unique, inherent rheological properties. In putty form it is extremely plastic, soft, and readily moldable. When mixed with sand or other cementitious materials, it contributes the necessary *plasticity* to the mortar in order to make it workable under the trowel. This enables the mason to spread mortar more easily and to fill mortar joints more completely, contributing both to superior productivity and workmanship. The plasticity imparted to the mortar causes the mortar to fill more completely the surface indentations, pores and irregularities of the units, thereby developing intimacy of contact at the mortar-unit interface, a requisite for *strong bond.* Stated another way, such soft, plastic mortars facilitate the imbedding of the masonry unit. The lime further contributes an *adhesiveness* to the mortar, causing the mortar to stick to the units.

Interrelated with plasticity is *water retentivity*. Highly plastic mortars characterized by a high lime content possess high water-retentive qualities. This means that these mortars tenaciously retain their moisture for much longer periods and resist the suction imposed from contact with dry, hot porous masonry units. Such units will quickly absorb the water from a mortar deficient in plasticity, causing the mortar to "pancake" before it has bonded to the unit. Thus, this water-retentive property contributes further to a strong bond and watertight masonry.

For interior and exterior plastering, the plastic, water-retentive, and adhesive properties are also important for workability, resistance to suction from lath or adjoining plaster coat, and bonding power. But another physical property is also important — an extremely minute, *micron particle size,* including submicron sizes. Thus, lime finish coats can be readily troweled into a dense, compact, marble-like, smooth surface or into a dense, textured surface. For masonry and exterior plaster its fine particle size, coupled with its bulkiness, increases the *sand-carrying* capacity of the mortar. By being able to employ a higher proportion of sand, *economy* is enhanced since sand is much less costly than lime and cement.

Lastly, lime contributes some *strength* to mortar and plaster by gradually absorbing carbon dioxide from the atmosphere and reverting to a carbonate form. The most important reason for using some portland cement in mortar is to provide high early strength and secondarily for greater ultimate strength.

Other attributes for building lime are:

- Low-efflorescence potential due to its relatively high chemical purity.
- Contributes some degree of resilience and flexibility to mortar under stress.
- On hardening, mortars do not shrink and rupture the bond.
- Its slow-setting quality permits retempering, resulting in less mortar wastage.
- Its pronounced white color yields a lighter colored mortar or plaster surface.
- Provides some measure of autogenous healing or the ability of a mortar to reconstitute or reknit itself if voids are present, or small cracks develop, contributing to mortar integrity and bond.

Section I

SPECIFICATIONS FOR

FINISHING HYDRATED LIME

Designation NLA-1

(Refer to ASTM Designations C 6 and C 206)

1. Uses. Finishing hydrated lime is used primarily as the major constituent of the finish coat in plastering. It may be used, however, wherever mason's hydrate is specified.

2. Scope. This specification covers two types of finishing hydrated lime, viz.: the so-called "normal" type, produced by hydrating under atmospheric pressure, in which a relatively large amount of the oxides are unhydrated; this will be referred to as Type N. It also covers hydrate produced by any method in which relatively large amounts of the oxides are hydrated; this will be referred to as Type S. Both of these types are applicable to either high calcium or dolomitic hydrates.

3. Chemical Composition. Both types of finishing hydrated lime shall conform to the following chemical composition, calculated to the basis as indicated:

	Type N	Type S
Calcium and Magnesium Oxides (minimum non-volatile basis)	95%	95%
Carbon Dioxide (maximum as-received basis)		
If sample is taken at point of manufacture	5%	5%
If sample is taken at any other point	7%	7%
Unhydrated Oxides (maximum as-received basis)	No Requirement	8%

4. Fineness. Both types of finishing hydrated lime shall conform to the following:

Maximum percent retained on a No. 30 (595-micron) sieve 0.5

Maximum percent retained on a No. 200 (74-micron) sieve 15.0

5. Pitting and Popping. Both types of finishing hydrated lime when gauged with plaster and tested in the steam bath in the manner outlined in the "Methods of Test" shall show no pits or pops.

6. Plasticity. The putty made from Type N normal finishing hydrate shall have a plasticity figure of not less than 200 when tested after a soaking period of not less than 16 hours nor more than 24 hours.

The putty made from Type S special finishing hydrate shall be accepted if it develops a plasticity figure of not less than 200 when tested after mixing or after soaking for any period not exceeding 24 hours.

7. Methods of Test. All methods of test are specified or described in Section VII.

Section II

SPECIFICATIONS FOR

MASON'S HYDRATED LIME

Designation NLA-2

(Refer to ASTM Designation C 207)

1. Uses. Mason's hydrated lime is used principally as a constituent of mortars and concrete. It may be used in stucco and base coat plaster.

2. Scope. This specification covers two types of hydrate, N and S. Type N covers the type usually referred to as mason's hydrated lime. Type S covers the product characterized principally by its ability to develop high early plasticity and high water retentivity. Both of these types are applicable to either high calcium or dolomitic hydrates.

3. Chemical Composition. Both types of mason's hydrated lime shall conform to the following chemical composition calculated to the basis as indicated below:

	Type N	Type S
Calcium and Magnesium Oxides (minimum non-volatile basis)	95%	95%
Carbon Dioxide (maximum as-received basis)		
If sample is taken at point of manufacture	5%	5%
If sample is taken at any other point	7%	7%
Unhydrated Oxides (maximum as-received basis)	No Requirement	8%

4. Fineness. Both types of mason's hydrated lime shall leave a residue of not more than 0.5% on a No. 30 (595-micron) sieve.

5. Plasticity. Type S mason's hydrated lime shall have a plasticity figure of not less than 200 when tested after a soaking period of not more than 15 minutes. Type N mason's hydrated lime shall not be required to meet this test.

6. Water Retentivity. Type N mason's hydrated lime shall have a water-retentivity figure of not less than 75 when tested as a mortar made either from the dry hydrate or from putty from that hydrate which has been soaked from 16 to 24 hours. Type S mason's hydrated lime shall have a water retentivity of not less than 85 when tested as a mortar made from the dry hydrate.

7. Methods of Test. All methods of test are specified or described in Section VII.

Section III

SPECIFICATIONS FOR

QUICKLIME

LUMP, PEBBLE, CRUSHED, GRANULAR AND GROUND

Designation NLA-3

(Refer to ASTM Designation C 5)

1. Definition.

(a) *Lump Lime* is the usual designation for the product resulting from the calcination of limestone in a shaft kiln. It ranges in size from approximately 4 to 12 in. in diameter.

(b) *Pebble Lime* is the usual designation for the product resulting from the calcination of limestone ranging in size from approximately ¼ in. to 1¾ in. in diameter.

(c) *Granular Lime* is the usual designation for the run of kiln material, the top size of which is approximately ¼ in.

(d) *Crushed Lime* is the usual designation for the product resulting from the crushing of the run of kiln material down to a definite top size.

(e) *Ground Lime* is the usual designation for the product resulting from the crushing and grinding of quicklime down to a definite sieve size. The usual products all pass either a No. 6 (3.36-mm), No. 10 (2.00-mm) or No. 20 (841-micron) sieve.

(f) *Pulverized Lime* is the usual designation for the product which has been ground to a fineness such that 100% will pass a No. 20 (841-micron) sieve.

(g) All of the above forms of quicklime are applicable to either high calcium or dolomitic lime.

2. Uses. Lump, pebble, granular, crushed, pulverized and ground quicklime, after being slaked to a putty, are used for the same purpose as the mason's hydrates. They may also be used for finishing coats of plaster, providing the resulting putties meet the requirements for plasticity, fineness, and pitting and popping.

3. Chemical Composition. All quicklime shall conform to the following chemical composition calculated to the basis as indicated:

Calcium and Magnesium Oxides (minimum non-volatile basis)	95%
Carbon Dioxide (maximum as-received basis)	
If sample is taken at point of manufacture	5%
If sample is taken at any other point	7%

4. Residue. All quicklime when tested in accordance with the method outlined under NLA-7 (part 9) shall show a residue of not more than 3%.

NOTE: Pebble lime shall not be broken down but shall be tested in the form received.

5. Fineness. When any of these quicklimes are to be used for finishing coats of plaster, the slaking and aging of the putty shall be carried out according to the directions given in Section VII. The portion of the putty passing the No. 20 (841-micron) sieve shall then show no more than 0.5% of residue on a No. 50 (297-micron) sieve based on the weight of dry lime in that portion of the putty.

6. Pitting and Popping. When quicklime is to be used for the finishing coat of plaster, the putty made in accordance with the directions outlined in Section VII shall show no pitting or popping.

NOTE: When testing quicklime putty for pitting and popping, a weight of putty shall be used which would be equivalent to approximately 75 g. of quicklime.

7. Plasticity. When quicklime is to be used for the finishing coat of plaster, the putty made in accordance with the directions outlined in Section VII shall have a plasticity figure of not less than 200.

8. Methods of Test. Directions for preparation of putty for test and instructions for all tests are included in Section VII.

Section IV

SPECIFICATIONS FOR

PLASTER AND STUCCO

Designation NLA-4

The specifications for interior plaster and exterior plaster (stucco) are adapted from the following current specifications of the American Standards Association:

ASA A 42.1	Standard Specifications for Gypsum Plastering
ASA A 42.5	Standard Specifications for Lime-Cement Stucco

INTERIOR PLASTER FOR FINISH COAT

1. Materials.

(a) *Gypsum Gauging Plaster* shall conform to ASTM specification C 28-63.

(b) *Keene's Cement* (for gauging) shall conform to ASTM specification C 61-64 or to Federal Specification SS-C-161 (1956) as an allowable alternate.

(c) *Hydrated Lime:*

1. *Special Finishing Hydrated Lime* shall conform to Designation NLA-1 on p. 5, which is adapted from ASTM specification C 206-49 for Type S hydrated lime. Its use is unrestricted.

2. *Normal Finishing Hydrated Lime* shall conform to Designation NLA-1 on p. 5, which is adapted from ASTM specification C 6-49 for Type N hydrated lime. This type of lime is restricted in its use to furred or suspended plaster bases or where plaster is applied over metal lath, wire cloth or fabric, gypsum lath, and similar plaster bases, as long as the plaster is not in direct contact with a solid backing (poured concrete and unit masonry).

(d) *Quicklime* shall conform to Designation NLA-3 on p. 7, which is adapted from ASTM specification C 5-59 (Quicklime for Structural Purposes). After the quicklime is slaked and soaked according to the manufacturer's directions, the resulting lime putty shall not have a total unhydrated oxide content in excess of 8% (calculated as CaO — MgO on an as-received basis). In the event of failure to meet this unhydrated oxide requirement, it will be considered the equivalent of normal finishing hydrated lime and is subject to the same use restriction cited above in (c)2.

(e) *Aggregates:*

1. *Sand* for use in sand-float finish coats shall comply with the following gradation:

Sieve Size	Retained on Sieve Percent by Weight Max.	Min.
No. 16 (1,000 micron)	0	0
No. 30 (595 micron)	20	50
No. 50 (297 micron)	50	70
No. 100 (149 micron)	80	100

The fine sand shall consist of substantially sharp, angular particles, not rounded.

2. *Fine Aggregates* for use in special lime putty, gypsum trowel finish coats, shall be graded within the following limits:

	Percent Retained on Sieve			
	Perlite by Volume		Fine Silica Sand, Marble Dust, Pulverized Limestone by Weight	
Sieve Size	Max.	Min.	Max.	Min.
No. 20 (841 micron)	0	—	0	—
No. 30 (595 micron)	10	—	10	—
No. 100 (149 micron)	100	40	100	40
No. 200 (74 micron)	100	70	100	70

(f) *Bonding Agents* may be used at the discretion of the specifier.

(g) *Water* for mixing shall be clean, fresh, and suitable for domestic consumption.

2. Finish Coat Proportions.

(a) *Lime Putty, Gypsum Trowel Finish.* This finish shall be mixed in the proportions of 1 part by volume of gauging plaster (calcined gypsum) to not more than

4½ parts by volume of lime putty. This mix is approximately equivalent to:

One (100 lb.) bag of gypsum gauging plaster to:
not more than 6 (50 lb.) bags of hydrated lime or
not more than 6.75 cu. ft. of lime putty or
not more than 52.5 gal. of lime putty.

Where the basecoat aggregate is perlite or vermiculite, the lime putty, gypsum trowel finish specified herein shall, in addition, contain fine pulverized aggregate such as fine silica sand or other additives meeting the sieve analysis of (e)2 above in the following proportions:

Not Less Than	Not More Than	
½ cu. ft.	1 cu. ft.	per 100 lb. bag of gypsum gauging plaster used in the finish
or ⅛ cu. ft.	¼ cu. ft.	per 50 lb. bag of hydrated lime
or 1 gal.	2 gal.	per 50 lb. bag of hydrated lime
or 1 gal.	2 gal.	per cu. ft. of lime putty
or 1 pint	1 qt.	per gal. of lime putty.

(b) *Keene's Cement-Lime Putty Finish.* This finish may be medium hard or hard finish.

1. *Medium Hard Finish.* This finish shall be mixed in the proportions of 100 lb. of Keene's cement to not more than 50 lb. of dry hydrated lime. The specified mix is equivalent to:

One (100 lb.) bag of Keene's cement to:
not more than 1 (50 lb.) bag of hydrated lime or
not more than 100 lb. of lime putty or
not more than 1⅛ cu. ft. of lime putty or
not more than 8¾ gal. of lime putty.

2. *Hard Finish.* This finish shall be mixed in the proportions of 100 lb. of Keene's cement to not more than 25 lb. of dry hydrated lime. The specified mix is equivalent to:

One (100 lb.) bag of Keene's cement to:
not more than 25 lb. of hydrated lime or
not more than 50 lb. of lime putty or
not more than ⅝ cu. ft. of lime putty or
not more than 4½ gal. of lime putty.

NOTE: For any of the above proportions, up to ½ cu. ft. of fine aggregate complying with (e)2 above may be added to the mix for each 100 lb. of Keene's cement.

3. When mixing Keene's cement-lime putty finish mechanically, the water shall be put into the mixer first, then the lime, the aggregate (if used) and finally the Keene's cement.

(c) *Keene's Cement-Lime Putty Sand Float Finish.* This finish shall be mixed in the proportions of 2 parts of lime putty, 1½ parts of Keene's cement, and 4½ parts of sand, by volume.

EXTERIOR PLASTER (STUCCO)

1. Materials.

(a) *Lime:*

1. *Hydrated Lime* — Both normal (Type N) and special (Type S) lime shall conform to Designation NLA-1 on p. 5, which is adapted from ASTM specifications C 6-49 and C 206-49, respectively. There is no restriction in the use of either type.

2. *Quicklime* shall conform to Designation NLA-3 on p. 7, which is adapted from ASTM specification C 5-59. Its use is unrestricted.

(b) *Portland Cement:*

1. *Standard type* shall conform to ASTM specification C 150-64.

2. *Air-entraining type* shall conform to ASTM specification C 175-64.

(c) *Aggregates* for base coats shall consist of clean, fine, granular material composed of natural sand or of sand prepared from stone or blast furnace slag or other materials of like characteristics. The aggregate shall be free of loam, silt, soluble salts, and vegetable matter. The aggregate shall conform to the following gradation:

Retained on Sieve	Percentage Retained Min.	Max.
No. 4 (4760 micron)	—	0
No. 8 (2380 micron)	0	10
No. 16 (1190 micron)	10	40
No. 30 (590 micron)	30	65
No. 50 (297 micron)	70	90
No. 100 (149 micron)	95	100

NOTE: While it is recognized that coarsely graded aggregate is desirable for stucco work, the use of substantial proportions of lime in lime-cement stucco eliminates much of the tendency toward shrinkage of the stucco. Where the grading specified above does not provide sufficient fines for good workability, finely graded materials of the types listed in Section (c) should be blended with the existing aggregates. In no case shall the combined blended aggregate fall outside the limits of the grading requirements of the above table.

For finish coats the aggregate shall be natural, dry sand conforming to the requirements of the table in (c) above, except that all of the aggregates shall pass a #10 sieve, unless otherwise specified.

(d) *Hair or fiber* for fibered stucco shall be goat, cattle, or deer hair, or pure manila fiber of good quality, ½ to 2 in. in length. All hair and fiber shall be free from grease, oil, dirt, or other impurities.

(e) *Water* shall be clean, fresh, and suitable for domestic consumption.

2. Stucco Proportions.

(a) *Base Coats Applied to Metal Reinforcement (Lath)*

1. *The stucco* shall consist of two coats: scratch and brown, of ⅜ in. thickness each.

2. *The mortar* shall be a mixture of special fibered or unfibered lime in the following proportions:

Ingredient	Scratch Coat		Brown Coat	
	Dry Mix	Putty Mix	Dry Mix	Putty Mix
Hydrated lime	2 bags (100 lb.)	—	2 bags (100 lb.)	—
Lime putty	—	1 part by vol.	—	2 parts by vol.
Portland cement	1 bag (94 lb.)	1 part by vol.	1 bag (94 lb.)	1 part by vol.
Aggregate	750 lb.	6 parts by vol.	900 lb.	9 parts by vol.
Hair or fiber	6 lb./cu.yd.	6 lb./cu.yd.	3 lb./cu.yd.	3 lb./cu.yd.

(b) *Base Coats Applied to Solid Backing (Concrete or Masonry)*

1. *Base coat* consists of two-coat, doubled up work of ¾ in. total thickness rather than scratch or brown coats.

2. *The stucco* may be fibered or unfibered and shall be proportioned as follows:

Ingredient	Dry Mix	Putty Mix
Hydrated lime	2 bags (100 lb.)	—
Lime putty (stiff)	—	2 parts by vol.
Portland cement	1 bag (94 lb.)	1 part by vol.
Aggregate	750 lb.	9 parts by vol.
Hair or fiber	6 lb./cu. yd.	6 lb./cu. yd.

(c) *Finish Coats.* Proportions to be used in stucco finish coats are as follows:

Ingredient	Lime-Cement Trowel or Textured Finish		Sand Finish	
	Dry Mix	Putty Mix	Dry Mix	Putty Mix
Hydrated lime	2-4 bags (100-200 lb.)	—	2-4 bags (100-200 lb.)	—
Lime putty	—	2½-5 cu. ft.	—	2½-5 cu. ft.
Portland cement	1 bag (94 lb.)	1 bag (94 lb.)	1 bag (94 lb.)	1 bag (94-lb.)
Silica sand or marble dust	—	—	300-500 lb.	300-500 lb.

NOTE: In all of the above interior and exterior plaster coats, the adjoining plaster coat to which the new coat is applied should be scratch-scored or roughened in order to develop a strong, permanent bond or "keying" action.

Section V

SPECIFICATIONS FOR

MORTARS FOR USE IN UNIT MASONRY

Designation NLA-5

(Refer to ASTM Designation C 270)

1. Scope.

The Specifications for Mortars for Use in Unit Masonry shall be applicable sections of ASTM Designation C 270. Two alternate specifications are provided as follows:

Property Specifications in which the acceptability of the mortar is based on the properties of the ingredients (materials) and the properties (water retention and compressive strength) of samples of the mortar mixed and tested in the laboratory (Sections 2 to 7 and 10).

Proportion Specifications in which the acceptability of the mortar is based on the properties of the ingredients (materials), the proportions of these ingredients, and the water retention of samples of the mortar mixed and tested in the laboratory (Sections 2, 3, and 8).

Unless data are presented to show that the mortar meets the requirements of the property specifications, the proportion specifications shall govern. Mortar shall be accepted under only one set of specifications.

2. Materials.

Materials used as ingredients in the mortar shall conform to the requirements specified in the following Paragraphs (a) to (f):

(a) *Cementitious Materials.* — Cementitious materials shall conform to the following specifications of the American Society for Testing and Materials:

Portland Cement. — Type I, II, or III of the Specifications for Portland Cement (ASTM Designation: C 150), or type IA, IIA, or IIIA of the Specifications for Air-Entraining Portland Cement (ASTM Designation: C 175).

Portland Blast-Furnace Slag Cement. — Type IS or ISA of the Specifications for Portland Blast-Furnace Slag Cement (ASTM Designation: C 205).

Portland-Pozzolan Cement (for use in property specifications only). — Type IP and IPA of the Specifications for Portland-Pozzolan Cement (ASTM Designation: C 340) when fly ash is the pozzolanic material.

Slag Cement (for Use in Property Specifications Only). — Type S or SA of the Specifications for Slag Cement (ASTM Designation: C 358).

Quicklime. — Specifications for Quicklime for Structural Purposes (Designation NLA-3).

Hydrated Lime. — Specifications for Hydrated Lime for Masonry Purposes (Designation NLA-2).

(b) *Aggregates.* — Specifications for Aggregate for Masonry Mortar (ASTM Designation: C 144).

(c) *Water.* — Water shall be clean and free of deleterious amounts of acids, alkalies, or organic materials.

(d) *Admixtures or Mortar Colors.* — Admixtures or mortar colors shall not be added to the mortar at the time of mixing unless provided for in the contract specifications, and after the materials are so added, the mortar shall conform to the requirements of the property specifications.

(e) *Antifreeze Compounds.* — No antifreeze liquid, salts, or other substances shall be used in the mortar to lower the freezing point.

NOTE 1: Calcium chloride, when provided for in the contract specifications, may be used as an accelerator in amounts not exceeding 2 per cent by weight of the portland cement content of the mortar.

(f) *Storage of Materials.* — Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material.

3. Measurement and Mixing.

(a) *Measurement of Materials.* — The method of measuring materials for the mortar used in construction shall be such that the specified proportions of the mortar materials can be controlled and accurately maintained (Note 2).

NOTE 2: The weights per cubic foot of the materials are considered to be as follows:

Material	Weight, lb. per cu. ft.
Portland cement	94
Portland blast-furnace slag cement	94 (approx.)
Hydrated lime	40
Lime putty*	80
Sand, damp and loose	80 lb. of dry sand

(b) *Mixing Mortars.* — All cementitious materials and aggregate shall be mixed for at least 3 min. with the maximum amount of water to produce a workable consistency in a mechanical batch mixer (Note 3).

NOTE 3: Hand mixing of the mortar may be permitted on small jobs, with the written approval of the purchaser outlining hand mixing procedure.

(c) Mortars that have stiffened because of evaporation of water from the mortar shall be retempered by adding water as frequently as needed to restore the required consistency. Mortars shall be used and placed in final position within 2½ hr. after mixing.

Property Specifications

4. Mortar.

(a) Mortar conforming to the *property specifications* shall consist of a mixture of cementitious material and aggregate conforming to the requirements of Section 2, the measurement and mixing requirements of Section 3, and, in addition, the requirements in Sections 5-7, and 10.

(b) No change in the proportions established for mortar accepted under the property specifications shall be made nor shall materials with different physical characteristics be utilized in mortar used in the work unless compliance with the requirements of the property specifications is reestablished.

5. Aggregate Ratio.

The damp, loose volume of aggregate in the mortar shall be not less than two and one fourth times nor more than three and one half times the total separate volumes of cementitious materials used.

6. Water Retention.

Mortar of the materials and proportions to be used in the construction, mixed to an initial flow of 100 to 115, shall have a flow after suction of not less than 70 percent.

7. Compressive Strength.

The average compressive strength of three 2-in. cubes of laboratory prepared mortar shall be not less than the strength given in Table I for the mortar type specified. Mortar mixed to a flow suitable for use in laying masonry units shall not be required to meet the strength given in Table I for the mortar specified.

Table I. — Compressive Strength of Cubes For Mortar Types

Mortar Type	Average Compressive Strength at 28 Days, psi
N	750
O	350
K	75

Proportion Specifications

8. Mortar

Mortar conforming to the *proportion specifications* shall consist of a mixture of cementitious materials and aggregate conforming to the requirements of Section 2, the measurement and mixing requirements of Section 3, and in addition the requirements of Sections 9 and 10. The mortar shall be proportioned within the limits given in Table II for each mortar type specified.

Table II. — Mortar Proportions By Volume

Mortar Type*	Parts by Volume of Portland Cement, or Portland Blast-Furnace Slag Cement	Parts by Volume of Hydrated Lime or Lime Putty	Aggregate, Measured in a Damp, Loose Condition
N	1	1	6
O	1	2	9
K	1	3	12

* ASTM Specification C 270 includes two additional Mortar Types M and S. These are high-cement mortars which contain insufficient lime to impart to the mortar the beneficial properties of lime.

9. Water Retention

Mortar of the materials and proportions used in the construction, mixed to an initial flow of 100 to 115, shall have a flow after suction of not less than 70 percent.

* All quicklime should be slaked according to the manufacturer's directions. All quicklime putty, except pulverized quicklime putty, should be sieved through a No. 20 (841-μ) sieve and allowed to cool until it has reached a temperature of 80 F. Quicklime putty should weigh at least 80 lb. per cu. ft. Putty that weighs less than this may be used in the proportion specifications, if the required quantity of extra putty is added to meet the minimum weight requirement

Methods of Testing

10. (*a*) *Water Retention* — Water retention shall be determined in accordance with Section 28 of ASTM Designation C 91, except as noted in Sections 6 and 9.

(*b*) *Compressive Strength Test.* — Compressive strength shall be determined in accordance with Sections 24 and 25 of Specifications C 91, with the following exceptions:

(*1*) The mortar shall be of the materials and proportions intended for use in the construction, mixed to a flow of 100 to 115.

(*2*) Mortar cubes for compressive strength tests of mortars of types N and O shall be kept in the molds on plane plates in a damp closet, maintained at a relative humidity of 90 percent or more, for from 48 to 52 hr. in such a manner that the upper surfaces shall be exposed to the moist air. They shall then be removed from the molds and placed in a damp closet until tested. The cubes for compressive strength tests of type K mortar shall be kept in the laboratory air at a temperature of 70 ± 5 F for the entire curing period.

Section VI

SPECIFICATIONS FOR

LIME IN CONCRETE

Designation NLA-6

Materials

1. Hydrated Lime. Mason's or finishing hydrated lime, Type N or S, shall conform to the National Lime Association specifications for these materials.

2. Portland Cement. Portland cement shall conform to ASTM Specifications C 150.

3. Concrete Aggregates. Aggregates shall conform to ASTM Specifications C 33.

4. Water. Only clean, clear water of potable quality shall be used in preparing concrete.

Mixing

5. Hydrated lime shall be weighed and placed in the mixer at the same time as the portland cement.

Proportions

6. Hydrated lime shall be used in concrete in an amount not to exceed 6 percent by weight of the portland cement. Such usage improves workability, decreases segregation, minimizes honeycombing, and makes the hardened concrete more watertight.

Section VII

SPECIFICATIONS FOR

METHODS OF TEST

Designation NLA-7

The following designated or described methods of test shall be used to determine whether the limes conform to the requirements established in the foregoing specifications.

1. Sampling. The methods for sampling, inspection, packing, and marking quicklime and hydrated lime shall be prescribed in the ASTM specifications C 50.

2. Chemical Composition. The methods for chemical analysis shall be those prescribed by ASTM Specifications for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime, C 25.

3. Preparation of Putty from Quicklime. The method for preparation of putty from quicklime which is to be used for test shall be that prescribed in ASTM Specifications for Quicklime for Structural Purposes, C 5. The quicklime shall be slaked according to the manufacturer's directions. The resultant lime putty shall be stored until cool.

4. Physical Testing. The methods for all of the physical tests that follow except water retention refer to ASTM C 110, "Physical Testing of Quicklime and Hydrated Lime." The water-retention test is adapted from ASTM C 91, "Specifications for Masonry Cement."

5. Fineness. The method of fineness of hydrated lime shall be that prescribed for determination of residue in ASTM C 110, Section 4, which involves wet screening on the Nos. 30 and 200 sieves.

6. Standard Consistency of Lime Putty. The method for determining the standard consistency of lime putty shall be that described in ASTM C 110, Sections 5 and 6, which is described as follows:

Mix 300 g. of hydrated lime with sufficient water to form a thick putty and stir to assure intimate mixing. Type N hydrate putty is stored and covered with a wet cloth for sixteen to twenty-four hours before testing; Type S hydrate putty can be tested immediately after preparation.

The equipment employed is a modified Vicat apparatus. Putty is added flush to the top of a nonabsorbent mold, 4 cm. in height, 7 cm. at base, and 6 cm. at top, which rests on a glass base. A plunger is lowered in contact to the putty surface and an initial reading taken. Release the plunger for thirty seconds and take another reading. Standard putty consistency is obtained when a penetration of 20 mm. ± 5 mm. is obtained in thirty seconds. If putty is substandard in consistency, recombine the sample and original putty, add more water, mix for two to three minutes, and make a retest as above. If penetration then exceeds standard, the sample should be discarded and a new one prepared.

7. Popping and Pitting. The method for popping and pitting shall be that prescribed in ASTM C 110, Sections 13 and 14, which is described as follows:

Mix 100 g. of hydrated lime with sufficient water to bring to consistency as required in Section 6 above. Mix into above putty, 25 g. of gauging plaster, adding more water as required to maintain workable consistency. Spread on a glass plate to make a pat at least 6 by 8 in. by approximately ⅛ in. thick. Trowel to a smooth finish. Allow to stand in laboratory overnight. Then place specimen and plate on rack in steam bath so that water is not in contact with specimen to be tested. Provide a sloping cover over specimen to prevent condensed steam from dripping onto surface of a specimen. Raise temperature of water in steam bath to boiling and maintain at boiling for 5 hours. Remove specimens from bath and examine for pops and pits.

NOTE: The gauging plaster used for this test should be tested without addition of lime in the above manner to ensure its freedom from pops. If any pops are found, another sample of gauging plaster must be provided.

8. Plasticity. The method for measuring plasticity shall be that of C 110, Sections 7-10. A special apparatus known as the Emley Plasticimeter is used in this test (see Fig. 1). A similar type mold as employed in the standard consistency test (Section 6) is lubricated with water, placed on a porcelain or disposable plaster-base plate, and filled flush to the top with a lime putty of standard consistency. The mold is then removed carefully and vertically without distorting the mound of putty. The base plate with putty is on a turntable. A motor rotates the turntable at one revolution in $6\frac{2}{3}$ minutes and rises a $\frac{1}{13}$ in. per revolution. Before rotation is commenced, a disc from above is placed in contact with the paste. This is intended to simulate the action of a trowel applying lime putty to an absorbent wall base. Timing is critical. The turntable should not be started in motion until exactly 120 sec. after the putty is first added to the mold. Thus, the following must be precisely recorded: Starting time, time of starting motor, and scale reading *each* minute until completion of test. The test is complete when:

1. The scale reaches 100 or
2. The scale value falls (reading less than previous one) or
3. The scale reading remains constant for three consecutive readings or the specimen has visibly ruptured or broken bond with the base plate.

The plasticity value is calulated from the following equation:

$$P = \sqrt{F^2 + (10T)^2}$$

where:

P = plasticity figure
F = scale reading at end of test
T = time in minutes of total test from time putty was first placed in mold.

Essential to some degree of reproducibility in this test is a base plate with the proper degree of absorption that has been standardized at not less than 40 g. of moisture absorption when the plate is immersed in water at room temperature for 24 hours. Meticulous care of base plates is necessary — cleaning thoroughly, drying, etc., to maintain proper degree of porosity.

8. Water Retentivity. The method of determining water retentivity is adapted from ASTM C 91, Sections 26-28. In this test the water-retention value $= \frac{\text{Flow after suction}}{\text{Flow immediately after mixing}} \times 100$. A description of the apparatus and test methods for determining flow before and after suction follows:

(a) *Apparatus*

1. Flow table, mold for casting specimen, and caliper, which shall conform to ASTM C 230. The flow table shall be used for the adjustment of the consistency of the mortar. This apparatus consists of a rigid frame with a flat circular top, so mounted on a vertical shaft that it can be raised and dropped through a fixed height of ½ in. by means of a rotating cam. The top shall be of non-corrodible metal 10 in. in dia. and with the attached shaft shall weigh 9 ± .01 lb. The frame shall be attached rigidly to a concrete pedestal, which shall be at least 8 in. in dia., 25 in. in height, and weigh at least 100 lb. The mold shall be of non-corrodible material, 4 in. I.D. at the base, 2¾ in. at the top, and 2 in. high.

2. Suction apparatus shall conform to ASTM C 91 (see Fig. 2). This apparatus consists of a water aspirator controlled by a mercury relief column and connected by way of a three-way stopcock to a funnel upon which rests a perforated dish. A mercury manometer should be connected as shown to provide a check on the vacuum. A synthetic rubber gasket is sealed to the top of the funnel and shall be coated with petrolatum or light cup grease during a test to insure a seal between funnel and dish. The perforated dish shall be made of nonabsorbent material. Hardened, very smooth, not rapid filter paper shall be used. It shall be of such diameter that it will lie flat and completely cover the bottom of the dish.

3. Steel straightedge, not less than 8 in. long and not less than $\frac{1}{16}$ nor more than $\frac{1}{8}$ in. in thickness.

4. Laboratory mixer, which shall be an electrically-driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in ASTM C 305, Section 2a, b, and c.

(b) *Procedure*

1. *Proportioning and Mixing.* The mortar tested shall be composed of 1 part by volume of cementitious material to 3 parts by volume of Ottawa sand, the latter comprising equal parts of graded Ottawa sand and 20-

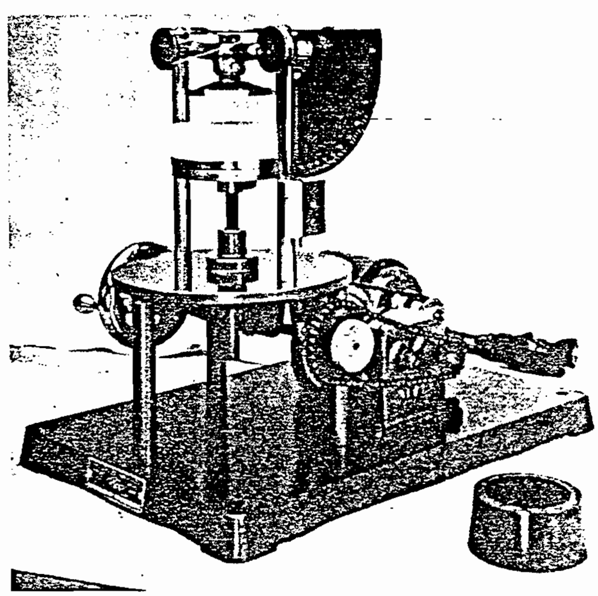


Fig. 1 — Emley Plasticimeter Apparatus.

30 Ottawa sand. The bulk densities of the materials shall be considered as follows: hydrated lime, 50 lb./cu. ft.*; portland cement, 94 lb. cu. ft.; and sand, 80 lb. cu. ft. (on dry basis). Thus, a 1:1:6 lab mix will be proportioned in a ratio of 50 gm. lime, 94 gm. cement, and 480 gm. sand (actually three times these quantities would be used to provide enough material for running the test). The proportions used for a straight lime mortar would be 300 g. lime to 1440 g. sand.

Mechanical mixing shall be carried out in accordance with ASTM C 305, Section 6, with sufficient water added to produce an initial flow of 110 ± 5%.

2. *Determination of Initial Flow.* In making this determination (adapted from ASTM C 109) wipe the flow-table top clean and dry and place the flow mold at the center. After mixing, fill the mold with mortar in two approximately equal increments, tamping each layer 20 times. Using a straightedge, cut off the mortar to a plane surface, flush to the top of the mold. After wiping the table top clean and dry, lift the mold away from the mortar. Immediately thereafter, drop the table a distance of ½ in. 25 times in 15 sec. The flow is the resulting increase in average base diameter of the mortar mass, measured on at least four diameters, expressed as a percentage of the original base diameter. Make trial mortars with varying percentages of water until the specified flow is obtained. Make each trial with fresh mortar.

3. *Applying Suction and Determining Flow*

(a) Adjust the mercury relief column for maintaining a vacuum of 2 in., as measured on the manometer. Seat the perforated dish on the greased gasket of the funnel. Place a wetted filter paper on the bottom of the dish. Turn the stopcock to apply the vacuum and check for leaks and to determine that the required suction is obtained. Then turn the stopcock to shut off the vacuum.

(b) Immediately after making the initial flow test, return the mortar on the flow table to the mixing bowl and remix for 15 sec. at medium speed. Next, fill the perforated dish with the mortar to slightly above the rim. Tamp 15 times, using enough pressure to ensure filling the dish. Smooth off the mortar using a straightedge, then cut off the excess mortar by drawing the straightedge across in two cutting strokes.

(c) Turn the stopcock to apply the vacuum to the funnel. After suction for 60 sec., quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then using a bowl scraper, plow and mix the mortar in the dish for 15 sec. Then place the mortar in the flow mold and determine the flow after suction, using the procedure in (2) above.

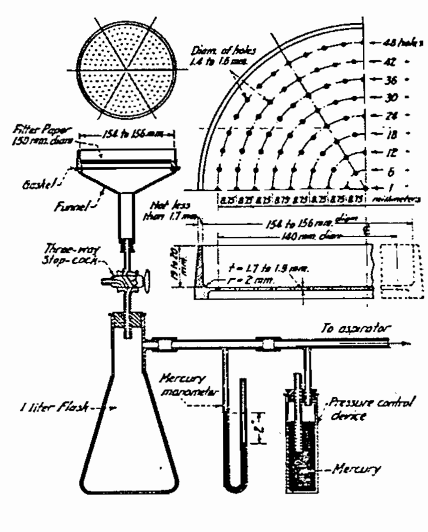
The entire operation shall be carried out rapidly and without interruption, and shall be completed within 11 min.** after the start of mixing to determine the initial flow.

9. Residue of Quicklime. The method for determining the residue of quicklime shall be that of ASTM C 110, Section 3, which is described as follows:

The insoluble matter (core and impurities) in quicklime is determined by weighing the residue and calculating its percent from the weight of the original sample, which is at least 5 lb. Lump material should be first crushed so that it passes a 1-in. sieve; pulverized material is tested as received. The sample is then slaked carefully into a putty of maximum yield and is allowed to stand for one hour. The putty is then washed through a No. 20 sieve by a stream of water at moderate pressure. Washing is continued until the residue remaining visually appears to be nothing but coarse sand-like particles. The residue is then dried at a constant weight at a temperature of 212° to 225° F., and the percentage residue calculated.

* Actually, the bulk density of hydrated lime is approximately 40 lb./cu. ft., but 50 lb. is used here to correspond to the typical bag weight, thus emulating general field practice of using full bag proportioning.

** When Type N hydrates are used, the total elapsed time can be extended to 30 min., the limit prescribed in the older water-retentivity test in ASTM C 110. The reason is that more time is needed for soaking Type N lime to generate its full water-retentivity potential. The value obtained in 11 min. might be unrealistically low, compared to field values.



NOTE: Gasket to be synthetic rubber. Stopcock 4-mm. Bore of tubing at least 4 mm. Check valve or water trap, or both, suggested for connection to aspirator.

Fig. 2 — Apparatus Assembly for the Water-Retention Test.