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Lath Fastening: An Examination of the Suitability of Prescriptive Requirements

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ABSTRACT

Adhered masonry veneer and exterior portland cement-based plaster (stucco) have been successfully applied over lath fastened to exterior framing members in accordance with prescriptive lath fastening requirements provided in ASTM C1063, Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster, for decades. Over the last 25 years, ongoing data collection and improved modeling has led to a better understanding of wind load pressures, and design and construction standards have been revised accordingly. In general, this resulted in increased design wind pressure values, particularly in hurricane-prone regions. However, the ASTM C1063 prescriptive spacing requirements have not changed since the standard's inception in 1986. With this increase in wind load pressures, the adequacy of the prescriptive fastening requirements in high wind regions has been questioned. It has been suggested that additional fasteners should be added between framing members to provide additional pull-off resistance even though this would violate other ASTM C1063 requirements. This paper examines the existing ASTM C1063 prescriptive fastening requirements and presents a comparative analysis of available laboratory test results to date to determine the suitability of the existing requirements.

KEYWORDS

adhered masonry veneer, lath, lath fastening, stucco, wind resistance

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INTRODUCTION

In the United States, metal lath has been successfully used to support adhered masonry veneer and exterior stucco cladding systems for decades; use of nonmetallic lath (NML), particularly in corrosive environments, has increased since NML industry standards were adopted in 2014. Despite the development of new materials and technology in cladding materials as well as advancements in understanding and modeling wind loads, the prescriptive requirements for fastening of lath has been unchanged since ASTM C1063 was first published in 1986. It is interesting to note that, as will be discussed later, these requirements were originally based on lath product geometry and had nothing to do with performance.

Unlike the prescriptive lath fastening requirements, wind loading of cladding systems has been studied in detail over the past 25 years, with improvements in data collection and advanced modeling resulting in more stringent building codes requiring more complex design wind load calculations. In general, design wind loads have increased, particularly in hurricane-prone regions such as the Gulf Coast and southeastern coastline of the United States. In turn, these higher wind loads resulted in higher demands on the lateral resistance of exterior wall cladding systems. However, despite these drastic changes in wind load computations, prescriptive lath fastening requirements remained unchanged.

This paper discusses the history of the prescriptive lath fastening requirements and summarizes transverse load testing performed by various independent laboratories on sample panels constructed in accordance with ASTM C1063 fastening requirements. The resulting ultimate loads determined from testing are then compared to anticipated wind pressures to assess the adequacy of the existing prescriptive requirements.

HISTORY

Unlike modern materials whose installation requirements typically are based on testing and engineering analysis, the requirements for lath fastening were driven by the geometry of the material and simple convenience. Since at least the first national standard was published in 1946 by American Standards Association (ASA) [1] (later to become American National Standards Institute [ANSI]), expanded metal lath has been fabricated in sheets that measure 737 mm (29 in.) in width. Of this width, 25 mm (1 in.) was provided for lapping purposes (which was the origin of the ASTM C1063 side lap requirement), resulting in a 711-mm (28-in.) span. Fastening was performed at the quarter points, thereby resulting in a 178-mm (7-in.) on center spacing. Simply put, the prescriptive fastener spacing was a legacy of what was easy to install in the field while anecdotally providing satisfactory performance. This prescriptive fastening requirement was included in the 1971 successor standard published by ANSI [2] that subsequently served as the basis for ASTM C1063 in 1986 [3]. Notably, this fastener spacing requirement is independent of lath type, fastener type, or substrate material [4]. Given the wide variety of materials that can be used, including, but not limited to, cold-formed steel framing gage, stud size, and wood species, there are hundreds, if not thousands, of potential combinations of fastener, lath, and substrate with a one-size-fits-all fastener spacing requirement.

With the advent of the International Code Council (ICC) model building codes in 2000, ASTM C1063 became a referenced standard, thereby codifying the prescriptive fastening requirement [5,6]. The most recent editions of the ICC codes, the 2024 International Building Code (IBC) and 2024 International Residential Code (IRC), continue to require compliance with ASTM C1063 for the installation of lath to support adhered masonry veneer and stucco [7,8]. However, prior to 2021, the IRC required a reduced fastener spacing (152 mm [6 in.]) than ASTM C1063 [9]; this was revised in 2021 to match the ASTM C1063 requirement [10]. Since 2021, the IRC has permitted installation of additional fasteners between wood framing members only [10], which contravenes the ASTM requirement that fastening between the framing members is to be avoided [4].

Since 2009, the IRC has included a provision requiring exterior claddings to be designed to resist wind pressures [11]; a similar requirement was added to the 2024 IBC [7]. These code requirements led to questioning regarding the prescriptive fastening requirements of ASTM C1063, which were not based on testing or engineering analysis: namely, if the prescriptive fastening requirements satisfy code-prescribed wind resistance requirements, if they need to modified to provide additional fasteners between framing members, or if the requirements need to be limited to use below a certain wind pressure.

LABORATORY TESTING

Test Specimens

Recent testing by multiple independent laboratories was performed on specimens constructed using traditional three-coat stucco applied over different lath products attached to a variety of framing materials using different types of fasteners. Each specimen was tested under negative transverse loading in accordance with ICC-ES AC191 or ASTM E330to gain a general understanding of the performance of mechanically-attached lath under lateral loading.

Specimens were constructed from the following materials:

- Studs: 92.1 mm (3.625 in.) or 152 mm (6 in.) cold-formed steel (CFS) in either 33 mil or 54 mil thickness; or nominal 2 x 4 or 2 x 6 No. 2 Spruce-Pine-Fir (SPF) wood
- Sheathing: Open-stud (“None”), exterior gypsum sheathing only (“Exterior”), or exterior gypsum sheathing and interior gypsum drywall (“Both”)
- Lath: 298 g/m^2 [8.8 oz/yd^2] ASTM C1788 NML, 1.4 kg/m^2 [2.5 lb/yd^2] or 1.8 kg/m^2 [3.4 lb/yd^2] ASTM C847 diamond mesh expanded metal lath (EML), or 18 mm x 38 mm [0.7 in. x 1.5 in.] or 38 mm x 38 mm [1.5 in. x 1.5 in.] ASTM C933 welded wire lath (WWL)
- Lath Fasteners: #6 or #8 screws (with and without washers) or 16-gauge staples

Test reports for specimens using other materials (such as wood-based sheathing, woven wire lath, or nails) were not available. A total of 15 unique combinations were tested per the matrix in Table 1.

As indicated in Table 1, only three tests were performed using the maximum permitted lath fastener spacing of 178 mm (7 in.). Two tests (both in welded wire lath) were performed using a fastener spacing of 127 mm (5 in.) due to designated fastening locations inherent to the product as determined by the grid pattern established by the manufacturer. The remaining 10 tests were performed using a fastener spacing of 152 mm (6 in.) in accordance with the residential code requirements in effect at the time of testing.

Test Results

For ease of review, the independent laboratory test results are reported separately based on the backup wall construction material with CFS specimen results summarized in Table 2 and wood stud results in Table 3.

Structural failure of the CFS framing in Specimen Types A, D, and I was unrelated to the spacing of lath fasteners, therefore results associated with framing failure were excluded from further analysis. The controlling ultimate lateral load for CFS stud specimens was -7.95 kPa (-166 psf) for 1.4 kg/m^2 EML fastened with #8 screws at 152 mm (6 in.) on center into 152 mm-deep by 33 mil-thick studs with gypsum sheathing and drywall.

As with the test results for the CFS-framed specimens, structural failure of Specimen Types F and H was unrelated to the spacing of lath fasteners and again excluded from further analysis. The test results for the remaining wood-framed specimens indicated that fastener withdrawal was the predominant failure mechanism. The controlling ultimate lateral load for wood stud specimens was -4.40 kPa (-92 psf), which was governed by pull-out of the staples used to fasten 1.8 kg/m2 EML to 2x4 open stud wood framing.

Table 1: Test Specimen Matrix

Specimen Type	Number of Specimens	Studs	Sheathing	Lath	Lath Fasteners	Fastener Spacing, mm (in.)
A	3	92.1 x 33 CFS	Exterior	1.4 EML	#8 Screws	152 (6)
B	3	152 x 54 CFS	Exterior	1.4 EML	#8 Screws	152 (6)
C	3	2 x 6 Wood	None	1.4 EML	#8 Screws	152 (6)
D	3	92.1 x 33 CFS	Exterior	1.8 EML	#8 Screws	152 (6)
E	3	152 x 54 CFS	Exterior	1.8 EML	#8 Screws	152 (6)
F	3	2 x 6 Wood	None	1.8 EML	#8 Screws	152 (6)
G	2	2 x 6 Wood	None	1.4 EML	Staples	178 (7)
H	3	2 x 4 Wood	None	NML	Staples	152 (6)
I	3	92.1 x 33 CFS	None	NML	#6 Screws with Washers	152 (6)
J	3	2 x 4 Wood	None	18 x 38 WWL	Staples	127 (5)
K	3	2 x 4 Wood	None	1.8 EML	Staples	178 (7)
L	3	2 x 4 Wood	None	38 x 38 WWL	Staples	127 (5)
M	3	2 x 4 Wood	None	1.4 EML	Staples	178 (7)
N	1	152 x 33 CFS	Both	1.4 EML	#8 Screws	152 (6)
O	1	152 x 33 CFS	Both	1.4 EML	#8 Screws with Washers	152 (6)

Table 2: Laboratory Test Results for CFS Stud Specimens

Specimen Type	Stud Length, cm (in.)	Average Ultimate Load, kPa (psf)	Failure Mode
A	122 (48)	-7.13 (-149)	Framing failure
B	122 (48)	-18.96 (-396)	Stucco cracking
D	122 (48)	-7.80 (-163)	Framing failure
E	122 (48)	-17.72 (-370)	Fastener pull-through and Framing connection
I	244 (96)	-3.02 (-63)	Framing failure
N	244 (96)	-7.95 (-166)	Stucco cracking
O	244 (96)	-9.96 (-208)	Stucco cracking

Table 3: Laboratory Test Results for Wood Stud Specimens

Specimen Type	Stud Length, cm (in.)	Average Ultimate Load, kPa (psf)	Failure Mode
C	122 (48)	-19.06 (-398)	Fastener pull-through
F	122 (48)	-11.59 (-242)	Framing connection
G	244 (96)	Between -2.75 (-57.5) and -5.39 (-112.5)	First stucco crack (not loaded to failure)
H	244 (96)	-5.94 (-124)	Framing failure
J	122 (48)	-7.76 (-162)	Fastener withdrawal
K	122 (48)	-4.40 (-92)	Fastener withdrawal
L	122 (48)	-7.13 (-149)	Fastener withdrawal
M	122 (48)	-5.70 (-119)	Fastener withdrawal

ANALYSIS

Two potential failure mechanisms were analyzed based on the independent laboratory test results. First, the serviceability limit state of deflection was analyzed based on unfactored service loads. These results were compared to loads at first cracking where this data was available. Second, the structural strength limit state was analyzed by reducing the reported ultimate loads by a suitable safety factor. The allowable load for the system is the least of the service load that induces the maximum code-permitted deflection or the ultimate strength of the panel reduced by the safety factor.

Approximately half the laboratory testing was performed on specimens that were 122 cm (48 in.) tall. It appears this was done to intentionally cause a failure in the lath and lath fasteners rather than due to structural failure or excessive deflection of the framing, both of which become more likely to occur as span length increases. Although these short spans are not representative of typical construction, the use of short spans to force a failure in the lath attachment (as opposed to structural failure or framing deflection) was appropriate as the intent of the testing was to evaluate lath attachment alone. Although this test configuration did not replicate expected real-world conditions, this would not alter the end results or conclusions regarding lath attachment performance. Except where noted, deflection limits were computed for 244 cm (96 in.) span lengths for comparison to the structural load results.

Serviceability

For simply supported framing members subject to uniform load, the deflection is determined using Eq. (1), where Δ is the deflection, w is the unfactored applied load, L is the member length, E is the modulus of elasticity, and I is the second moment of area (sometimes referred to as the moment of inertia). Together, EI represent the bending stiffness of the stud section.

$$(1) \qquad \Delta = \frac{5wL^4}{384\,EI}$$

Solving for w yields Eq. (2):

$$(2) \qquad w = \frac{384\Delta EI}{5L^4}$$

In Eq. (1) and Eq. (2), w represents a uniform linear load. To convert this to a wind pressure value, it would then need to be divided by the tributary width of the studs, t_w. Substituting this in Eq. (2) yields Eq. (3), where W represents the wind pressure.

(3) $$W = \frac{384\Delta EI}{5t_w L^4}$$

Typical values for E and I for the wall studs in this study (based on an assumed steel stud flange width as this dimension was not given in the test reports) are provided in Table 4 [12,13,14]. The steel stud designations provided conform to Canadian Sheet Steel Building Institute product designations.

Table 4: Typical Stud Material and Section Properties

Stud	E, MPa (ksi)	I, x10^6 mm^4 (in.^{4})
362S162-33	203,000 (29,500)	0.229 (0.551)
600S162-33	203,000 (29,500)	0.746 (1.79)
600S162-54	203,000 (29,500)	1.19 (2.86)
2 x 4 No. 2 SPF	9,650 (1,400)	4.17 (5.359)
2 x 6 No. 2 SPF	9,650 (1,400)	14.1 (20.80)

The 2024 ICC codes establish a serviceability maximum deflection limit of L/360 for exterior walls with stucco finishes and L/240 for exterior walls with other brittle finishes, such as adhered masonry veneer [7,8]. However, ASTM C926 limits framing deflection to L/360 for stucco cladding [15]. Industry standards promulgated by the Brick Industry Association and Concrete Masonry & Hardscapes Association for thin brick and adhered concrete masonry veneer, respectively, also recommend limiting the deflection of backup construction to L/360 [16,17]. Based on the code requirements and industry standard recommendations, L/360 was used for this analysis. For a standard wall stud length of 244 cm (96 in.), the resulting maximum permissible deflection is 6.8 mm (0.27 in.).

By substituting the values in Table 4 into Eq. (3), assuming the studs are 244 cm (96 in.) long and spaced at 406 mm (16 in.) on center, and setting the deflection equal to the maximum deflection limit of 6.8 mm, the calculated wind pressures to produce the maximum permitted deflection are provided in Table 5. These calculations are based solely on the stud properties and conservatively ignore the contribution of any exterior sheathing or interior drywall to the bending stiffness of the section.

The load at first cracking in the stucco was included in test reports from some, but not all, of the independent laboratories. Specimens for which the load at first cracking were reported are listed in Table 6 with the corresponding load. Table 6 also includes the stud length and the calculated wind pressure at the maximum code-prescribed deflection limit for that stud length for comparison purposes.

Table 5: Calculated Wind Pressure at Maximum Deflection Limit of L/360

Stud	W, kPa (psf)
362S162-33	1.69 (35.3)
600S162-33	5.49 (115)
600S162-54	8.77 (183)
2 x 4 No. 2 SPF	0.78 (16.3)
2 x 6 No. 2 SPF	3.03 (63.2)

Table 6: Comparison of Reported Loads at First Crack to Calculated Wind Pressure at Maximum Deflection Limit

Specimen Type	L, cm (in.)	Load at First Cracking, kPa (psf)	W, kPa (psf)
G	244 (96)	Between 2.75 (57.5) and 5.39 (112.5)	3.03 (63.2)
J	122 (48)	5.08 (106)	12.5 (261)
K	122 (48)	3.88 (81)	12.5 (261)
L	122 (48)	5.17 (108)	12.5 (261)
M	122 (48)	3.02 (63)	12.5 (261)
N	244 (96)	4.98 (104)	5.49 (115)
O	244 (96)	3.49 (72.8)	5.49 (115)

In nearly all cases where the load at first cracking was reported, the load at first cracking was less than the calculated wind pressure at the code-prescribed maximum deflection limit for serviceability. It is therefore apparent that the code permits limited cracking of brittle finishes like adhered masonry veneer and stucco without such cracking necessarily constituting a serviceability issue.

Strength

The controlling ultimate loads determined from Tables 2 and 3 represent structural failure of the lath or lath fasteners within the test specimen; namely fastener withdrawal (pull out) or lath pull-over as illustrated in Fig. 1.

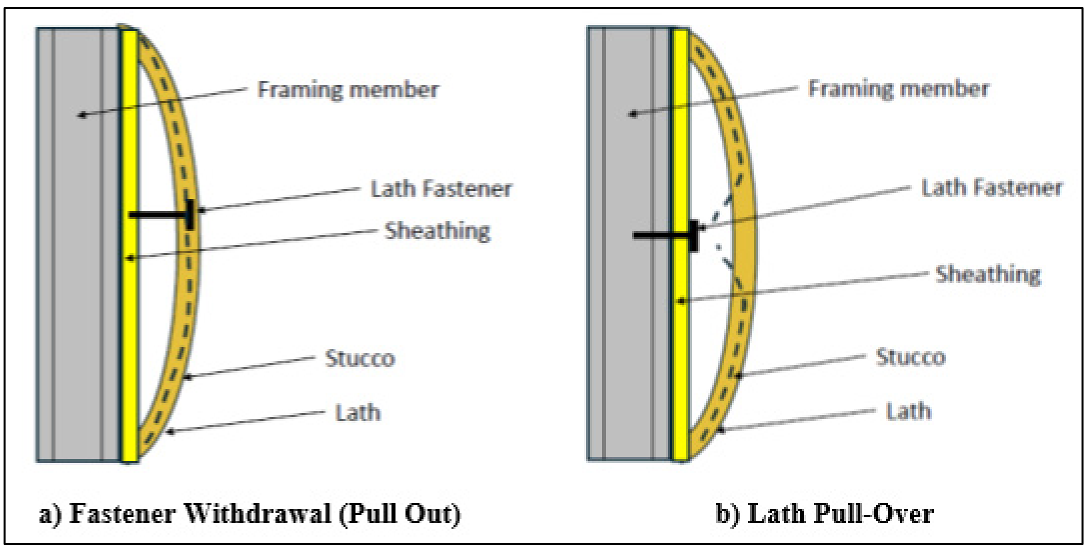

Figure 1: Lath failure modes included fastener pull out (a) or lath pull-over (b)

To determine the allowable load, these ultimate loads must be reduced by an appropriate safety factor based on reliability of materials, variability in loading, the acceptable probability of failure, and engineering judgement. In some cases, safety factors are specified in the building code; as an example, the code-prescribed safety factor for screws installed in CFS is 3.0 [12]. Although a safety factor of 3.0 is recommended by ICC-ES [18], a safety factor of 4.0 was used for purposes of this study. This value was chosen based on the high degree of variation observed in the test results, the uncertainty based on the limited sample size, and to account for the aforementioned change in the residential code fastener spacing requirements. These reduced allowable loads, along with the corresponding calculated service load for deflection from Table 5 for comparison purposes, are provided in Tables 7 and 8 for CFS and wood studs, respectively.

Table 7: Comparison of Allowable Strength Loads vs. Service Deflection Loads, CFS Studs

Specimen Type	Allowable Strength Load, kPa (psf)	Service Deflection Load, kPa (psf)
B	4.74 (99.0)	8.77 (183)
E	4.43 (92.5)	8.77 (183)
N	1.99 (41.5)	5.49 (115)
O	2.49 (52.0)	5.49 (115)

Table 8: Comparison of Allowable Strength Loads vs. Service Deflection Loads, Wood Studs

Specimen Type	Allowable Strength Load, kPa (psf)	Service Deflection Load, kPa (psf)
C	4.76 (99.5)	3.03 (63.2)
J	1.94 (40.5)	0.78 (16.3)
K	1.10 (23.0)	0.78 (16.3)
L	1.78 (37.3)	0.78 (16.3)
M	1.42 (29.8)	0.78 (16.3)

Testing performed on 92.1 mm x 33 mil CFS studs consistently resulted in failure of the structural framing rather than the stucco, lath, or lath fasteners and therefore was excluded from this analysis. Allowable strength loads controlled all the remaining CFS specimens tested, and the gage of the studs had a significant effect on performance. For example, Specimen Types B and E, with 54 mil studs, resisted nearly twice the load resisted by the 33 mil studs of Specimen Types N and O. The use of washers also appeared to affect performance: Specimen Type O with washers resisted approximately 25% more load than Specimen Type N with no washers. Because all four specimen types spaced fasteners at 152 mm (6 in.), it is unknown how significant the effect of fastener spacing at 178 mm (7 in.) per ASTM C1063 would be. No correlations regarding the effect of sheathing (whether installed on the exterior face of studs, installed on both stud faces, or no sheathing installed) could be determined based on the data.

The 2024 IBC references ASCE 7-22 for calculating wind loads [7]. For an enclosed, 10.7 m (35 ft)-tall, Risk Category II building with 33 mil studs at sea level in Exposure Category D with a basic ultimate wind speed of 58 m/s (130 mph) and no topographic effects, the design leeward wind pressure on a lath fastener in a corner zone would be approximately 1.99 kPa (41.5 psf) [19], which would meet the allowable lath fastener load from Table 7. For a high-rise commercial building, 33 mil studs typically would not be used; rather, a heavier gage, such as 54 mil studs would be more common. For a corner zone lath fastener into a 54 mil stud in a 152.4 m (500 ft)-tall Risk Category II commercial building at sea level in Exposure Category D with a basic ultimate wind speed of 60 m/s (135 mph), the design leeward pressure would be approximately 4.31 kPa (90 psf) [19], which would meet the allowable lath fastener load from Table 7. Therefore, for most buildings in the United States and Canada, the allowable strength loads in Table 7 for lath fastened to CFS framing likely would be adequate to resist the design wind loads, although the adequacy of the connection would be most dependent on the size and gage of the framing members. This conclusion is supported by the fact that widespread lath attachment failure (through either lath pull-over or lath fastener withdrawal or pull-out) has not occurred in practice in either country; instead, lath attachment in accordance with industry standards and local building codes have demonstrated many decades of successful performance.

Wood stud-framed specimens were controlled by deflection under service loads. In particular, Specimen Types K and M, which both tested lath fasteners spaced at the current code-prescribed maximum spacing, showed that the allowable strength load for the prescriptive fastening requirements can be expected to exceed the service deflection load. Similar to the results for CFS, the dimensions of the framing members seemed to have the greatest effect on performance as Specimen Type C with 2 x 6 wood studs resisted more than double the load resisted by any of the other specimen types, which all had 2 x 4 studs. Fastener spacing and lath type appeared to have a less pronounced, but still significant, effect on performance: Specimen Types J and L, with WWL and fasteners spaced at 127 mm (5 in.), resisted nearly 50% more load than Specimens Types K and M, with EML and fasteners spaced at 152 mm (6 in.). No correlations regarding the effect of fastener type could be determined based on the data.

CONCLUSIONS

The study resulted in the following conclusions:

- The existing prescriptive lath attachment requirements are independent of lath type, lath fastener type and size, substrate material, and design loading conditions.
- A limited amount of cracking in brittle finishes like adhered masonry veneer and stucco due to deflection that does not affect structural performance is permitted under the building code.
- For lath attachment to wood studs, the existing prescriptive requirements, while originally based on geometry and convenience of application, are adequate. This is because the exterior cladding assembly will meet the deflection limit under service loading before the allowable strength of the lath attachment is reached.
- For lath attachment to steel studs, the adequacy of the existing prescriptive requirements will vary depending on stud size and gage and the design wind loads on the building. Based on this analysis, the existing requirements are likely adequate for most buildings located within the United States and Canada that are subject to non-hurricane wind pressures. Low-rise buildings, which tend to use lighter gage studs, located in coastal regions that experience wind pressures greater than 1.99 kPa (41.5 psf) may not be suitable for the existing prescriptive lath fastening requirements and should be evaluated by an engineer. Similarly, high-rise buildings, which tend to use heavier gage studs, located in high wind velocity zones that experience wind pressures greater than 4.43 kPa (92.5 psf) may not be suitable for the prescriptive lath fastening requirements; design of lath attachment for such buildings should be evaluated by an engineer.

It should be noted that this analysis was limited to the materials tested. Recommendations for future research include testing of other lath materials, lath fastener types, lath fastener spacings, and substrate materials.

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