RECOMMENDED MESH ANCHORAGE DETAILS FOR STRAW BALE WALLS

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ABSTRACT

Experimental studies on full-scale straw-bale walls have demonstrated the adequacy of straw-bale wall systems for resisting lateral loads from wind or seismic actions. Critical to the performance of the wall system is the anchorage of mesh reinforcement to the bottom plate and to the roof bearing assembly or top plate. Reported in this paper are the results of experiments examining mesh strength, anchorage strength, and failure mode for a variety of reinforcement meshes (steel, plastic, and hemp) and anchorage details. Because of the potential for new wood preservative pressure treatments to cause corrosion, stainless steel staples driven pneumatically into pressure-treated sill plates were tested in addition to electro-galvanized staples driven pneumatically into untreated sill plates and a heavier gauge staple driven manually into an untreated sill plate. Recommended anchorage details are identified, considering not only the test results but also the many other factors that must be considered in developing reliable, economical, and constructible details.

KEYWORDS

mesh strength, anchorage details, staples

1. INTRODUCTION

The historical development of straw bale construction as vernacular architecture traditionally has relied upon the wisdom, ingenuity, resourcefulness and experience of field craftspeople and builders. Some early straw bale buildings (circa 1900-1925) in which no mesh was used in their plasters have survived very well to this day [1]. The growth in popularity of straw bale construction in recent years has led to straw bale construction being used for larger buildings, buildings that operate in the public realm, and buildings located in regions of high seismicity. While mesh-reinforced plasters may not be needed in all situations, the maturation of straw bale construction as a material of construction has brought the need to standardize "best of practice" details and to enable engineering approaches to be used for design, to promote reliable performance and to secure building official approval, particularly as straw bale construction is being used in a larger range of structural applications.

Of particular interest in this paper is the use of straw bale walls as designated elements of a lateral load resisting system. In recent tests [2] straw bale walls provided lateral load resistance on par with or surpassing that provided by plywood shear walls. The load is carried primarily by reinforced stucco or earth plaster skins applied to each side of the bale walls; the mesh reinforcement and its anchorage to the mud sill and roof bearing assembly play a critical role in the performance of the wall. The selection of suitable meshes and anchorage has been complicated by issues related to the recent introduction of wood preservatives that are highly corrosive to steel fasteners. To address these issues, this paper reports the strengths of several meshes (14- and 16-gauge steel, 'Cintoflex' C polypropylene, and hemp twine) and the strengths of various mesh anchorages, achieved using pneumatically driven electro-galvanized staples, pneumatically driven stainless steel staples, and manually driven hot-dipped galvanized staples. Recommendations are made for the anchorage of meshes in straw bale walls.

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2. MATERIALS

The following materials were used in the experimental tests:

Meshes

- 14 gauge 2 × 2 (51 × 51 mm), manufactured by the Bekaert Corporation in Van Buren, Arkansas and sold as "Weldmesh". This mesh was galvanized before welding and comes in a 4 × 100 ft (1.22 × 30.5 m) roll. This mesh is from the same batch that was used in the construction of the "large-scale" wall tests described in [2] and [3].
- 16 gauge 2 × 2 (51 × 51 mm) welded wire fabric used in stucco finishing. This mesh was galvanized before welding. The product is manufactured by Davis Wire and is described as "Best Lath D Double Paper."
- Hemp netting, made from hemp twine hand knitted into an 80 × 80 mm mesh. Panels are 6.71 × 22.86 m, obtained from Trade Marker International (product QHK001-080). See http://www.trademarker1.com/Contact_TMI.htm.
- 'Cintoflex' C 1.73 × 1.92 × 0.047 in. (44 × 49 mm) plastic polypropylene mesh. See http://www.tenaxus.com/agriculture/index.html .

The welded wire mesh is manufactured from a galvanized carbon steel wire in compliance with ASTM A641 [4] and satisfies ASTM C933 [5]. Although A641 specifies a maximum tensile strength of 75 ksi for the soft temper wires used in these meshes, no minimum strength is specified.

Staples

- Stainless Steel 16 gauge × 1.75 inch (44.5 mm) medium crown chisel point (SENCO N19BGBN)
- Electro-galvanized 16 gauge × 1.75 inch (44.5 mm) medium crown (SENCO N19BAB).
- Electro-galvanized 16 gauge × 1.25 inch (31.8 mm) medium crown (SENCO N15BAB).
- Electro-galvanized 15-gauge × 7/8 inch (22.2 mm) rounded shoulder staples, slash point, with 3/16-inch (4.8 mm) inner spread, manually driven.

Note: medium-crown staples have a 7/16-inch (11-mm) crown.

Sill Plates

- 4 × 4 (89 × 89 mm) Hem-Fir Standard and better, pressure treated with copper azole (labeled 0.21 pcf CA-B).
- 4 × 4 (89 × 89 mm) No. 2 Douglas Fir, without pressure treatment.
- 1 × 2 (19 × 38 mm) Pine, used along the side of a pressure-treated 4 × 4.

These materials were obtained at a local home supply store.

Building Paper

- Building paper (Fortified Flashing SK-10, Type 1, Grade A, Style 4) was used to provide a physical barrier between the mesh and pressure-treated wood in some configurations.

3. WIRE TESTS

Tension tests were performed on the individual "wires" of each mesh (a "wire" may refer to a wire of the steel mesh, hemp twine, or polypropylene strand). Longitudinal wires (extending in the direction of the roll) were selected for the tests, recognizing that the mesh typically is placed vertically along the height of a wall, and that the vertical wires in a wall are the ones that are subject to tensile forces in order to mobilize resistance to overturning associated with in-plane or out-of-plane loads. To obtain a representative sample, different longitudinal wires were selected across the width of the roll.

Each wire sample was subjected to a monotonic tension test in a Universal Testing Machine. The wire sample was positioned so that the weld to the transverse wire (or strand junction in the case of polypropylene mesh) as well as a short segment of the transverse wire on either side of the weld was located within the test region, between the testing machine grips at either end. However, for the hemp mesh, a straight length of twine (without knots) was positioned in the grips. The clear distance between the grips was approximately 25 mm in length. Wire specimen lengths were approximately 100 mm, leaving approximately 38 mm within the grips at either end. Although the weld was included in the length of wire tested and thus may indicate potential influences of the weld on the wire strength, a more severe and realistic condition would involve applying reversed cyclic loads simultaneously to the longitudinal and transverse wires.

Ultimate strengths and failure mode are reported in Table 1a for the four materials; sample statistics are reported in Table 1b. While the steel wires generally yielded over their lengths, the hemp mesh failed by the unraveling and sliding of individual fibers of the twine relative to one another. The strand of the polypropylene mesh often failed somewhere along its length between the grips, but in four instances the failure occurred at the junction of longitudinal and transverse strands, with the transverse strand splitting along its length and through the junction with the longitudinal strand.

TABLE 1A. Individual wire test results.

	14-Gauge Mesh		16-Gauge Mesh		Hemp		Cintoflex C	
Sample (Run) Number	Strength, lbs (kN)	Failure Location	Strength, lbs (kN)	Failure Location	Strength, lbs (kN)	Failure Location	Strength, lbs (kN)	Failure Location
1	408.5 (1.817)	Wire	327.6 (1.457)	Wire	55.2 (0.246)	Twine	76.2 (0.339)	Junction
2	326.7 (1.453)	Weld	340.9 (1.516)	Wire	55.9 (0.249)	Twine	77.1 (0.343)	Junction
3	386.9 (1.721)	Wire	338.5 (1.506)	Wire	66.3 (0.295)	Twine	75.6 (0.336)	Junction
4	404.1 (1.798)	Weld	353.2 (1.571)	Wire	61.8 (0.275)	Twine	75.2 (0.335)	Strand
5	391.3 (1.741)	Wire	299.4 (1.332)	Wire	53.9 (0.240)	Twine	76.6 (0.341)	Junction
6	363.3 (1.616)	Weld	297.1 (1.322)	Wire	54.8 (0.244)	Twine	76.9 (0.342)	Strand
7	414.4 (1.843)	Wire	306.2 (1.362)	Wire	54.8 (0.244)	Twine	69.7 (0.310)	Strand
8	412.7 (1.836)	Wire	292.2 (1.230)	Wire	—	—	72.4 (0.322)	Strand
9	365.7 (1.627)	Wire	320.2 (1.424)	Wire	—	—	73.7 (0.328)	Strand
10	366.4 (1.630)	Wire	324.2 (1.442)	Wire	—	—	76.8 (0.342)	Strand

TABLE 1B. Wire test summary statistics.

Material	Mean Strength, lbs (kN)	Coefficient of Variation	Diameter, in. (mm)	Area, in^2 (mm^2)	Mean Strength, ksi (MPa)
14-Gauge	384.2 (1.709)	7.34%	0.0796[1] (2.02)	0.00498 (3.21)	77.2 (532)
16-Gauge	330.0 (1.468)	6.27%	0.0636[1] (1.62)	0.00318 (2.05)	103.8 (716)
Hemp	57.9 (0.258)	8.12%	0.10 (2.5)	0.0079 (5.1)	7.3 (50)
Cintoflex C	75.2 (0.335)	3.19%	0.047[2] (1.2)	0.00173 (1.1)	43.5 (300)

[1]Mean of 10 measurements, consisting of two measurements offset by approximately 90 degrees per wire for five wires.
[2] Cross section is not circular; values are those reported in [6].

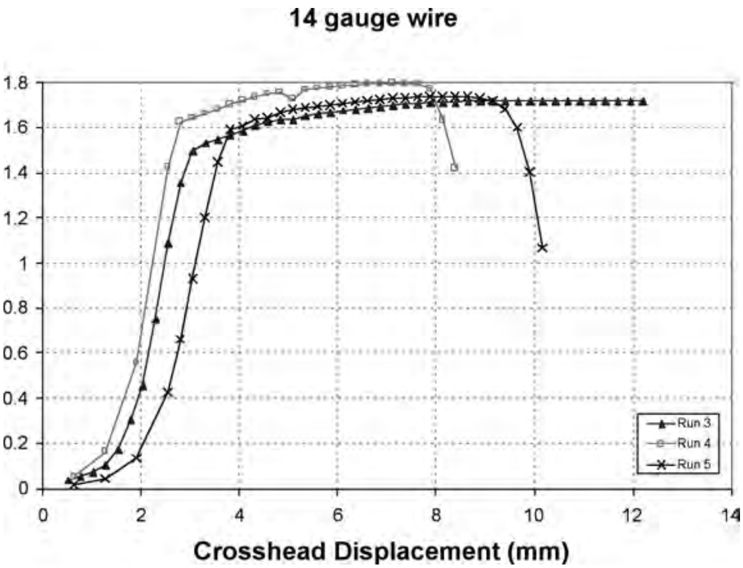


FIGURE 1. Load-displacement response for representative 14-gauge wires.

The measured diameters and corresponding areas of Table 1b correspond well to the American Steel & Wire (AS&W) reference standards for #14 and #16 gauge wire. The AS&W values for diameter are 0.0800 and 0.0625 in. (2.03 and 1.59 mm) and for area are 0.00503 and 0.00307 in^2 (3.24 and 1.98 mm^2) for the #14 and #16 gauge wire sizes, respectively.

Monotonic tension test results are plotted for a few representative wires in Figures 1 and 2. Total load is plotted as a function of the displacement of the loading head of the test machine. The measure displacements may include some slip at the grips of the test machine. The data were recorded manually. It is apparent that even the failure at the weld in Run 4 of the 14-gauge wires occurred after considerable yielding over the length of wire between the grips.

Because none of the mesh materials are manufactured to satisfy minimum strength requirements, there is no assurance that nominally identical materi-

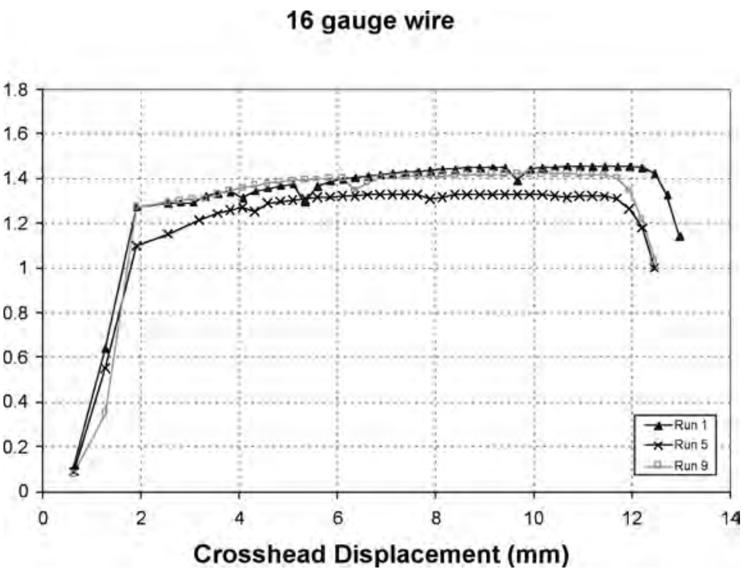


FIGURE 2. Load-displacement response for representative 16-gauge wires.

als will have strengths on par with those reported herein.

4. MESH ANCHORAGE TESTS

Anchorage of the mesh to a mud sill and roof bearing assembly is an essential part of providing a complete load path for resisting lateral forces. The widespread use of new chemical preservatives in pressure-treated wood members such as copper azole and ACQ that are more corrosive to steel has given impetus to develop practical corrosion-resistant details that are capable of fully mobilizing the strength of the mesh. The wood industry recommends the use of hot-dipped galvanized fasteners (with thicker coatings than for CCA treated lumber). Fastener manufacturers tend to recommend stainless steel fasteners over galvanized steel fasteners in wood treated with copper azole or ACQ. Hot-dipped galvanized staples are not manufactured for use with pneumatic staple guns. Stainless steel staples are available, although they cost approximately 8-10 times that of ordinary electro-galvanized staples.

The medium- and large-scale tests done as part of the EBNet Straw Bale Test Program (http://www.ecobuildnetwork.org) demonstrated that while a conventional 2×4 (nominally 38 × 89 mm) mud sill was inadequate for developing the strength of the 14-gauge mesh, a 4×4 (nominally 89 × 89 mm) mud sill with anchor bolts at 2-ft (610 mm) centers was sufficient to anchor 14-gauge steel mesh to the foundation. The anchorage was adequate to develop the strength of the 14-gauge mesh, without having pre-emptive failures occur at weld locations. The EBNet mesh anchorage tests determined that the strength of the 16-gauge mesh could not be developed even with a 4×4 mud sill because pre-emptive failures occurred at the welds between longitudinal and transverse wires.

Compared with the 16-gauge mesh, the welds between the 14-gauge wires may be more substantial, and thus provided the mesh with greater integrity for carrying loads in the EBNet tests. However, the larger welds may have led to pre-emptive failures in the individual wire tests, where three of the ten wires suffered pre-emptive failures at the weld (Section 3). The 14-gauge mesh tested in both investigations was obtained from the same manufacturing run.

In contrast, pre-emptive failures of the wires at the welds were not observed in the tests of individual 16-gauge wires (Section 3). It would appear that the 16-gauge mesh welds were not large enough to interfere with the capacities of the individual wires. Howerver, the reduced capacity of the welds to transfer load between longitudinal and transverse wires may have caused the mesh to have inferior performance in the EBNet tests.

The main objective of the mesh anchorage tests was to establish empirically the combinations of staple type, staple orientation, and mesh that are adequate to develop the strength of the mesh anchored into a 4×4 mud sill. A secondary objective was to identify a test method that adequately represent the potential for weld failures to interfere with the development of mesh strength as slip and redistribution develop in the mesh/staple system.

The configurations investigated are summarized in Table 2. Electro-galvanized staples were used with untreated mud sills, while stainless steel staples were used with pressure-treated mudsills. Building paper was used to prevent direct contact between the steel meshes and a treated mud sill. The shorter staples (1-1/4 inch or 32 mm legs) were used with the polypropylene and hemp meshes, while the longer staples (1-3/4 inch or 44 mm legs) were used with the steel wire meshes. Because the staple anchorage was believed to be weakest when the staples were driven parallel to grain, the 4×4 was rotated to select the face that most closely duplicated this orientation. The staples were driven to avoid crimping the wires. As a result, the contact between the staple and the wire varied from a loose to a snug fit.

Many designers are using an untreated 4×4 placed directly on top of a 1×4 (nominally 19 × 89 mm) Redwood mud sill. Although the entire detail was not tested, the anchorage to the 4×4 is represented by Configuration A. The large scale tests indicated that the steel mesh is severely worked under reversed cyclic loading in the vicinity of the staple; in effect, where the mesh passes from the inside face of the cement plaster (or stucco) to the middle of the cement plaster, where it is well protected. Configuration D aims to keep the mesh aligned in a vertical plane by using a 1×2 (nominally 19 × 38 mm) furring strip to anchor the mesh in the center of the plaster rather than at the inside face (Figure 3).

Generally, for the steel and polypropylene meshes, a segment of mesh containing 9 longitudinal wires

TABLE 2. Mesh anchorage configurations.

Configuration	Mesh	Mud sill	Staple Type	Staple Orientation
A	14-gauge	Untreated 4x4	Electro-galvanized, 1-3/4 in. legs	Diagonal at weld intersection
B	14-gauge	Pressure-treated 4x4 with building paper	Stainless steel, 1-3/4 in. legs	Diagonal at weld intersection
C	14-gauge	Pressure-treated 4x4 with building paper	Stainless steel, 1-3/4 in. legs	Horizontal above weld intersection
D	14-gauge	Pressure-treated 4x4 with untreated 1x2	Stainless steel, 1-3/4 in. legs	Diagonal at weld intersection
E	16-gauge	Pressure-treated 4x4 with building paper	Stainless steel, 1-3/4 in. legs	Diagonal at weld intersection
F	Cintoflex C	Untreated 4x4	Electro-galvanized, 1-1/4 in. legs	Horizontal above junction
G	Cintoflex C	Untreated 4x4	Manually-driven, 1 in. legs	Horizontal above junction
H	Hemp	Untreated 4x4	Electro-galvanized, 1-1/4 in. legs	Horizontal above knot
I	Hemp	Untreated 4x4	Manually-driven, 1 in. legs	Horizontal above knot

was stapled at its base to the 4×4 mud sill. The staples were placed in an alternating pattern over the lowest two transverse wires, which were centered (approximately) over the face of the 4×4 (see Figure 4a). Longitudinal wires were isolated from one another by cutting the transverse wires on either side above the rows of staples. The two longitudinal wires at either end of the sample were considered to provide a boundary at the periphery of the test region, which consisted of the innermost 5 wires. Again, giving consideration to anchorage provided by staples on either side of the wire being tested, the wires were pulled individually in the sequence identified in Figure 4a.

Exceptions to the preceding are as follows. For Configuration D, the staples were placed along a single transverse wire, with 3 additional staples placed at 7 inches (178 mm) on center to anchor the 1×2 to

FIGURE 3. 1x2 furring strip to anchor the mesh in a vertical plane (Configuration D).

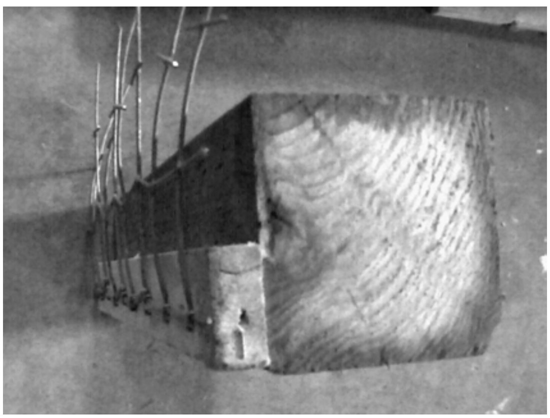
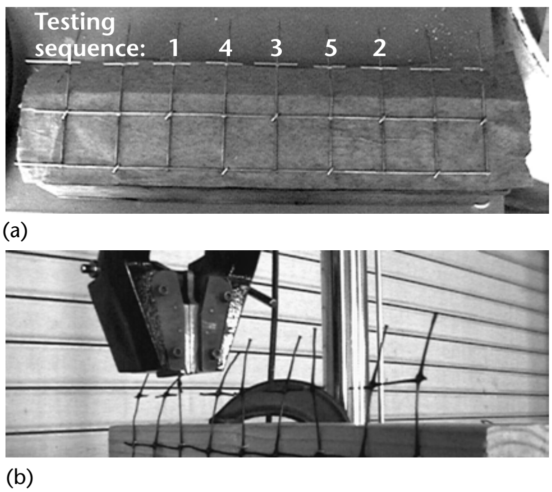


FIGURE 4. (a) detail showing alternating staples and sequence of individual wire tests; (b) test setup.



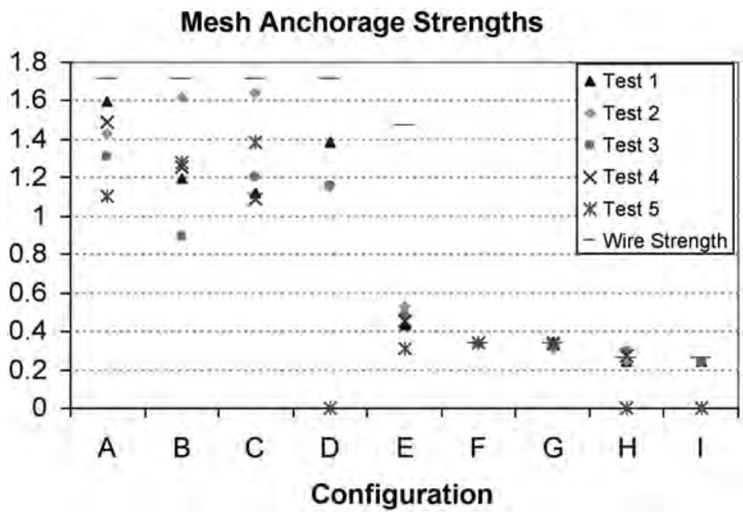


FIGURE 5. Comparison of mesh anchorage strength results with wire strengths..

the 4×4. For Configuration E, the sample was oriented such that the transverse wires of the panels were tested individually, and it is these wires that undulate in the mesh. For Configurations F and G, the polypropylene mesh was oriented so that tension was applied to the strands running in the long direction (1.92 in. or 48.8 mm). The large spacing of the hemp wires required that the staples be placed in a single row. In these cases a horizontally oriented staple was placed just above a knot. Three or four wires were tested, and the boundary consisted of a single wire on either side of the test region.

The adequacy of the staple anchorage was determined by testing the individual wires monotonically. While the monotonic tests are relatively simple and reliable, the tests do not replicate field conditions wherein the wires can be expected to be loaded more uniformly and under repeated cycles. On one hand, the testing of wires individually may place more severe demands on the welds at the transverse wire nearest the staple and along the length of the wire. On the other hand, monotonic demands are generally not as severe as reversed cyclic demands. Thus, interpretation of the results is necessary.

Figure 5 compares the strengths measured in the mesh anchorage tests with the mean individual wire strengths of Table 1b. It is apparent that the test procedure was not able to mobilize the strengths of the individual wires for Configurations A through E. There appears to be no obvious pattern of the strengths obtained relative to the test number, which might have occurred if the integrity of the adjacent wires or welds along the two transverse wires had been essential for resisting the applied load.

The failures for Configuration C were characterized by the staple pulling out from the 4×4 (see Figure 6). The failures for Configurations A, B, D, and E often involved wire fracture at the welds of the 14-gauge mesh or wire separation at the welds of the 16-gauge mesh (e.g. Figure 7). Yet, the 14-gauge wire used in Configurations A-D was fully developed in the large scale tests. This suggests that the test procedure used herein places more severe demands on the welds than are encountered in practical applications as wall reinforcement.

FIGURE 6. Pullout of staple (Configuration C).

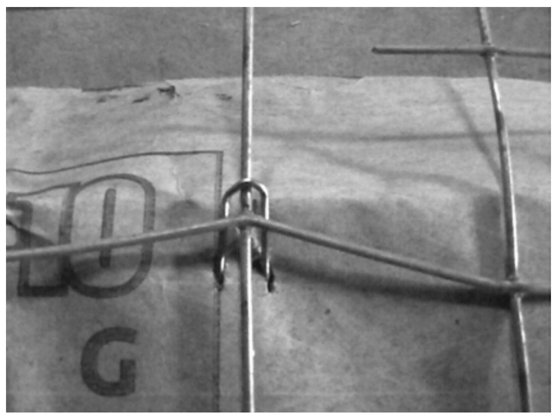


TABLE 3. Mesh anchorage test results

Test	Configuration A		Configuration B		Configuration C	
	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description
1	358.4 (1.594)	Transverse wire failed at weld	267.8 (1.191)	Transverse wire failed at weld	251.0 (1.117)	Staple pulled out
2	321.3 (1.429)	Wire necking to fracture	363.4 (1.616)	Transverse wire failed at weld	368.2 (1.638)	Staple pulled out
3	293.5 (1.306)	Staple leg snapped	201.4 (0.896)	Transverse wire failed at weld	270.9 (1.205)	Staple pulled out
4	334.2 (1.487)	Transverse wire failed at weld	281.7 (1.253)	Transverse wire failed at weld	244.9 (1.089)	Staple pulled out
5	248.6 (1.106)	Transverse wire failed at weld	286.6 (1.275)	Transverse wire failed at weld	311.4 (1.385)	Staple pulled out

Test	Configuration D		Configuration E		Configuration F	
	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description
1	311.5 (1.386)	Transverse wire failed at weld	97.4 (0.433)	Separation of wires from one another at weld	76.2 (0.339)	Strand failure at junction
2	260.4 (1.158)	Transverse wire failed at weld	118.2 (0.526)	Separation of wires from one another at weld	77.1 (0.343)	Splitting of transverse wire through junction
3	260.9 (1.161)	Transverse wire failed at weld	108.3 (0.482)	Separation of wires from one another at weld	75.2 (0.335)	Splitting of transverse wire through junction
4	—[1]	—	101.9 (0.453)	Separation of wires from one another at weld	76.6 (0.341)	Strand failure at junction
5	—[1]	—	70.2 (0.312)	Transverse wire failed at weld	75.7 (0.337)	Splitting of transverse wire through junction

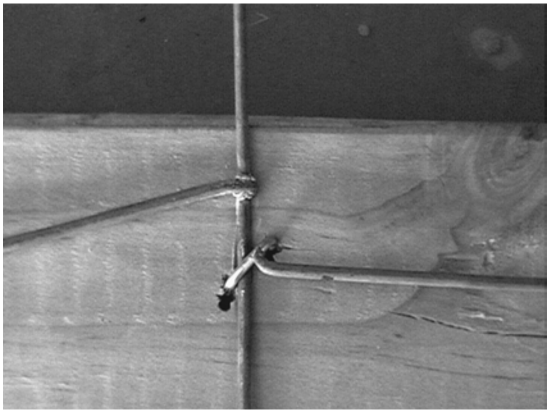
[1] Wires 4 and 5 were not tested.

Test	Configuration G		Configuration H		Configuration I	
	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description	Strength, lbs (kN)	Failure Description
1	78.4 (0.349)	Splitting of transverse wire through junction	55.2 (0.246)	Twine failure by unraveling	53.9 (0.240)	Twine failure by unraveling
2	69.8 (0.310)	Splitting of transverse wire through junction	55.9 (0.249)	Twine failure by unraveling	54.8 (0.244)	Twine failure by unraveling
3	73.5 (0.327)	Splitting of transverse wire through junction	66.3 (0.295)	Twine failure by unraveling	54.8 (0.244)	Twine failure by unraveling
4	75.2 (0.335)	Splitting of transverse wire through junction	61.8 (0.275)	Twine failure by unraveling	—[2]	—
5	76.9 (0.342)	Splitting of transverse wire through junction	—[1]	—	—[2]	—

[1] Wire 5 was not tested

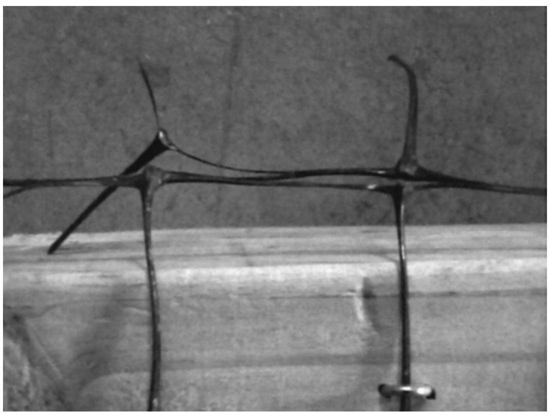
[2] Wires 4 and 5 were not tested

FIGURE 7. Failure of transverse wire at weld (Configuration A).



The staples in Configurations A, B, and D were able to support the loads transmitted prior to failure of the mesh weld, except in one instance in which an electro-galvanized staple leg failed. The highest tested strengths approached the mean strength of the 14-gauge wire, suggesting that these staples may well be adequate for the 14-gauge mesh, just as had been observed in the large-scale tests. Configuration C demonstrates that the staples should be oriented diagonally over the weld rather than horizontally above the weld. The increased likelihood of failure of the welds of the 16-gauge mesh, first observed in the medium-scale tests, is also evident in the low strengths obtained for Configuration E.

FIGURE 8. Lengthwise split of transverse strand and junction (Configuration G).



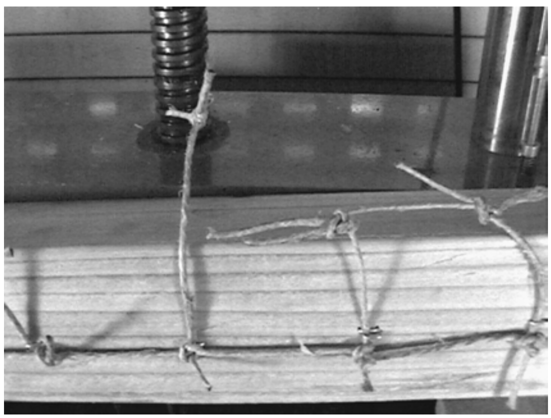
The lower strength polypropylene and hemp meshes were adequately anchored by the staples used in Configurations F, G, H, and I. A splitting failure of the polypropylene strand is shown in Figure 8. Unraveling of the hemp twine is shown in Figure 9.

5. RECOMMENDED STAPLE-MESH DETAILS

Based on the tests results described herein and those obtained in the earlier medium and large-scale tests, we recommend the following:

1. 14-gauge mesh: 16-gauge medium crown (7/16 in. or 11 mm) staples having 1-3/4 in. (44.5 mm) legs oriented diagonally over the welds are expected to be adequate for 14-gauge mesh. The staples should be installed at a depth that does not crimp the mesh (the mesh may be loose or snug against the 4×4). If the 4×4 mud sill is pressure treated, the mesh should not be in contact with the 4×4 and a stainless steel staple is necessary. Building paper may be used to provide a physical barrier between the mesh and pressure-treated lumber, or a 1×2 furring strip may be used with adequate fastening to the 4×4 (Configuration D) to separate the mesh from the treated 4×4 and align the mesh in the center of the plaster. An alternative is to use electro-galvanized staples with an untreated 4×4 over a 1×4 Redwood mud sill. The 14-gauge mesh should be used with a cement-based plaster.

FIGURE 9. Unraveling of twine—note the substantial elongation of one "wire" due to loading relative to the other wires, which have not yet been loaded. (Configuration H).



2. Polypropylene and hemp mesh: These meshes may be anchored using 16-gauge medium crown staples having 1-1/4 in. (32 mm) legs or using heavier gauge manually driven staples having 1 in. or longer legs. The staples should be oriented horizontally and located just above the strand junction or twine knot. Because of their lower stiffness, the polypropylene and hemp meshes generally should be used with an earth or lime plaster rather than a strong, rigid cement plaster. A lack of information about the long-term durability of hemp within earth and lime plasters suggests caution be exercised in using hemp in locations where strength must be maintained.

No tests were done to assess whether a shorter-length staple might be adequate for anchoring the 14-gauge mesh. Evidence from this and previous test series suggests that 16-gauge steel mesh should not be used in structural applications because the welds are prone to failure.

These recommendations are made on the basis of information currently available to the authors. Additional tests are planned to confirm the adequacy of these details using a modified test setup in which multiple wires are loaded simultaneously.

6. CONCLUSIONS

The vernacular origins of straw bale construction have left open many questions about mesh strengths and anchorage. The variety of mesh materials and anchorage details used to enhance the load-carrying capacity of the plasters on either side of a straw bale wall have to be selected with care to assure that a minimum strength level relied upon in design can be achieved. Ultimate strengths as well as the statistical variability in strengths for wires selected from 14- and 16-gauge steel meshes, from a 'Cintoflex' C polypropylene mesh, and from a hemp mesh were reported. Despite the range of manufacturing processes and inherent differences in the material characteristics, the coefficient of variation in the strengths of the four types of mesh were similar, ranging from about 3 to 8 percent.

The recent introduction of wood pressure treatment chemicals such as copper azole and ACQ, which are highly corrosive to steel fasteners, has resulted in a recommendation to use stainless steel staples with pressure-treated wood. An alternative to the costly stainless steel staples is to use conventional electro-galvanized staples to attach the mesh to an untreated 4×4 mudsill, which is separated from the foundation by an underlying Redwood 1×4 or other decay-resistant material. Both electro-galvanized and stainless steel 16-gauge pneumatically driven medium crown staples having 1.75 inch (44 mm) legs are recommended for anchoring the 14- and 16-gauge meshes. The staples should be oriented diagonally over the welds of the steel meshes to avoid staple pull-out.

While the tests of the 16-gauge wire did not indicate a propensity for the wires to fail at the welds, failures of the welds themselves caused separation of longitudinal and transverse wires. The poor performance of the performance of the 16-gauge mesh in both present and previous tests suggests that it should not be relied upon structurally, unless adequate performance is demonstrated in subsequent tests.

For the polypropylene and hemp meshes, the legs of the 16-gauge pneumatically driven staples may be reduced to 1.25 in. Alternatively, heavier gauge manually driven staples having 1-in. (25 mm) legs may be used for these meshes. The bulkiness of the hemp knots makes it preferable to orient the staples horizontally just above the knots, as tested herein. Only a horizontal staple orientation was tried for the polypropylene mesh in this test series, and this orientation proved to be acceptable for the polypropylene mesh.

The approach used to test the mesh anchorage, in which individual wires of a stapled mesh were tested separately, appeared to produce more severe demands on the steel wires at the locations of the welds (and thus may have induced failures at the welds at a lower load) than would have occurred had the wires been loaded more uniformly. An improved, standardized, method for testing mesh anchorage would be useful. Additional tests in which multiple wires are loaded approximately uniformly would be useful to confirm the recommendations developed herein.

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