

CTIOA Technical Committee Technical Bulletin



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Tile Exterior Veneer Lath, Scratch, Brown Coat Tensile and Shear Bond Strength Testing Report

A joint Study sponsored and conducted by CTIOA Technical Committee and Technical Services Information Bureau (representing the Lath, Plaster and Drywall for the Wall and Ceiling Industry)

PURPOSE OF PULL TEST

As a ceramic tile and stone tile industry committee, we discovered there were little to no information regarding performance test data for performing a tensile pull strength test on an exterior veneer tile (ceramic or stone) over a wire-reinforced mortar-bed/plaster wall assembly. There is a wide range of lab tests results and standards for tile bond shear strengths published within the industry and established as building code standards.

According to the current California Building Code (CBC) 2007 Edition Section 1405.9, as well as the 2009 International Building Code (IBC) section 1405.10, which references ACI 530 sections 6.1 and 6.3 for adhesion requirements, it states that adhesion developed between adhered veneer units and backing shall have a shear strength of at least 50 psi (345 kPa) based on gross unit surface area. On the other hand, manufacturers of thin-set adhesives show substantially higher shear bond values can be achieved (200 psi to 500 psi when tested in a laboratory with a porcelain tile per ANSI A118.4-5.2) with a wide range of thin-set adhesive products available today in the industry.

The CTIOA Field Report 82-2, published in 1982, suggested that a tensile pull test be performed on exterior veneer tile assemblies to determine if the tiles are adequately bonded. This report established a testing protocol and stated that a 50 psi tensile value should be considered the minimum acceptable value, even though the 50 psi tensile value is considered to be a greater bond strength than the building code minimum 50 psi shear value.

It was found that during field tensile pull tests of tile over plaster substrates (studs, lath, scratch and brown coats) that it was often that the substrates would cohesively fail, rather than the tile attachment to the substrates adhesively failing. Often the substrates would fail within itself (cohesively) at a tensile pull value that was substantially below the 50 psi minimum. This left a question as to whether the substrates were deficient or not. The building codes or the lath and plaster industry do not have any type of tensile pull test minimum requirements, physical property values report, or a test that is required to determine if the substrates is suitable or not for an adhered veneered system. So it is unknown as to how these types of plaster substrates should perform when tested.

The committee's plan was to fabricate different configurations of test panels of the entire support framing and tile assembly, which includes the scratch coat, brown coat, thin-set adhesive, and tile, to replicate as close as possible jobsite field conditions both from the tile installer point-of-view as well as from the lath and plaster trade view. The test results were documented and evaluated for not only failure values, but for noting which part of the mortar-bed assembly the failures occurred relative to each configuration tested. The intent was to determine what a reasonable tensile strength failure test value is over a plaster substrate.

PHASE I PULL TEST PANELS

The panels were constructed primarily with metal framing, covered with a water-resistive vapor-permeable barrier, metal lath, and a mortar scratch and brown coat. The dimensions of the panels are 18-inches by 23-inches. The framing members (studs) were placed so that the 6-inch x 6-inch tile sample was bonded to the center of the panel between the framing members. This was constructed as such to test the weakest portion of the mortar-bed assembly.

In today's projects, majority of the scratch and brown coats (base coats) of an adhered veneer projects are installed by the plastering trade, following an ASTM C 926 mix. These test panels were taken to a jobsite to have the base coat gunned applied. There were 16 test panels in phase I, the base coats for these test panels were of the following: 10 panels with a portland cement/lime and sand mix, 2 panels with a Paragon premixed "Wall Float," 2 panels with a Laticrete 8510 acrylic mortar admix mixed with water per their instructions, and 2 panels with a riverside cement/lime and sand mix. A 6-inch x 6-inch piece of Gascoigne Beige limestone was attached with thin-set to the panel with TEC Superflex (ANSI A118.4 modified thin-set mortar). A 6-inch x 6-inch metal pull bracket was then adhered with epoxy to the face of the limestone.

PHASE I TEST RESULTS

The testing and documentation was performed by Bureau Veritas North America, Inc., an objective and independent testing facility and engineering firm who performed and documented the testing, and who donated their time and equipment. Referring to the test data report produced, it is the committee's conclusion that after removing the one extremely low and one extremely high values of the tests that the average "failure value"¹ was 17 psi, with a range from 12 psi to 22 psi. The failures predominately occurred between the metal lath and the scratch coat.

VALUATION OF DATA

Considering all building codes, tile industry standards, and thin-set manufacturers only reference shear bond values for tile attachments, it is the opinion of this committee that a shear bond test of the mortar-bed assembly would be more valid and relevant to the industry.

PHASE II - SHEAR BOND TESTING

There were 3 open cavity test panels constructed for shear testing in essentially the same manner as in phase I with the base coats gunned applied. A modified version of ASTM C482 was used as the test protocol for the shear tests substituting the pure Portland cement paste bond coat with the specified thin-set mortar. The same limestone and thin-set adhesive was used as what was

¹ For this report, "failure value" or "failed" is describing the fracture or breaking point when the test is performed to force the tile assembly to fail. This does not suggest it is a failure within the system, but rather it demonstrates its limitation at its weakest link.

used in the tensile pull tests. The intent of this testing was to determine what are reasonable shear bond values as compared to the other tensile pull tests and industry standards.

The average shear bond strength was 346.3 psi with a range from 279.1 psi to 409.7 psi. Each panel failed primarily cohesively within the plaster base coat and often within the scratch coat at the metal lath.

PHASE II - TENSILE PULL TESTING

There were 6 testing panels constructed for additional tensile pull testing in essentially the same manner as in phase I with the base coats being gunned applied. The same limestone and thin-set was used. 3 panels were constructed with an open cavity as the phase I, using a Quikrete silo plaster mix for the base coat and the other 3 were constructed with a stud placed down the center of the panel using the same plaster mix as Phase I.

The primary purpose of these tests was to determine, 1) if the tensile pull test results would be higher when pulling over a stud versus pulling over an open cavity, and 2) if the silo mix would provide a different value than the ASTM C 926 mix as in phase I.

The average tensile pull value when pulling over the stud was 19.1 psi with a range from 15.1 psi to 24.4 psi. The average when pulling over an open cavity with the silo plaster mix was 18.9 psi with a range from 16.9 psi to 22.5 psi. Considering the standard deviation of these tests, the difference does not appear to be significant within the plaster mixes or with the pull tests. Each panel failed primarily cohesively within the plaster base coat and often within the scratch coat at the metal lath.

CONCLUSIONS

Pull Tests - It is the conclusion of this committee that with an average of 17 psi (range of 12 psi to 22 psi) tensile pull strength results in phase I and the average of 19 psi (range of 15.1 to 24.4) tensile pull strength values in phase II with failures within the scratch coat at the metal lath represents reasonable performance values. The overall average tensile pull strength of all the tested substrates was 18 psi.

Whether the tensile pull tests was performed over a stud or not, the results were not significant to the tensile pull value.

Shear Tests - The shear bond test results demonstrate that a tile properly bonded to a plaster substrate with an average tensile pull strength value of 18 psi using a quality ANSI A118.4 modified thin-set mortar can achieve an average shear bond value of 346.3 psi (range of 279.1 to 409.7). Since the test failures were primarily cohesively within the base coat, then the adhesive shear bond strength of the thin-set to tile or mortar must have been greater to some degree.

Codes

The California Building Code (CBC) 2007 Edition Section 1403.9 and the 2009 International Building Code (IBC), states a minimum of 50 psi shear bond strength between the backing and the tile shall be met, the shear bond strength tests clearly exceeded those requirements.

CBC has a section 1408.2 Adhered Veneer for DSA-SS & OSHPD 1, 2, and 4 requirements (basically public and government work) and states: "**1408.2.1 Bond strength and tests.** Veneer shall develop a bond to the backing in accordance with ACI 530, Section 6.3.2.4 (Adhered 50 psi minimum shear bond strength between backing and veneer). Not less than two shear tests shall be performed for the adhered veneer between the units and the supporting element. At least one shear test shall be performed at each building for each 5,000 square feet (465 m²) of floor area or fraction thereof." **1408.3 Inspection.** All veneer shall be inspected per Section 1704A.5.1. 2007.

Final Conclusion

It is clear that a tensile pull test over a plaster substrate is not an appropriate test method when trying to determine whether a tile meets the building code shear bond strength requirements. The shear bond strength test would be appropriate to verify that the building code requirement is met.

The building code suggests the whole tile assembly must achieve the minimum 50 psi shear bond strength between the tile and the substrate backing. Thus it implies that each component of the tile assembly of substrate, membrane, thin-set or tile should meet that requirement. So when tested if the tile assembly fails at any particular point, at a value less than 50 psi, then that point of failure would not meet the code minimum. If during testing the tile assembly fails cohesively in the tile, then the tile is the weak link. If it fails adhesively or cohesively in the thin-set then the thin-set is the weak link. If it fails cohesively within the membrane then the membrane is the weak link. If it fails cohesively in the base coat then base coat is the weak link. Being forced to fail for the test at any of those points does not suggest it did not meet the code requirement unless the shear bond strength average test values are below 50 psi.

Attached is an ISO 13007-2 Failure Pattern Chart that should be used to identify the point of failure as a result of the tile assembly being forced to fail during the testing.

Field Testing

It is recommended that field shear bond testing be performed on exterior veneer projects before and/or during the tile installation to demonstrate that the tile assembly is meeting applicable code requirements. The test should either be performed on a standalone mock-up of the specified tile assembly or it should be performed on an in-placed mock-up to remain as part of the work.

General

Considering that exterior veneer projects are considered high risk in terms of the potential damages a debonded tile could cause, it is recommended that the exterior veneer tile installation company demonstrate that they have more skills and experience at installing exterior veneers beyond just having a C54 tile installer license.

It is the committee's recommendation to incorporate these test data conclusions into any past CTIOA documents referring to adhered veneers. CTIOA Field Report 82-2 tensile pull test protocol should only be suitable for solid masonry or concrete backings and not appropriate for any applications over plaster or cementitious backing attached to framing. The CTIOA Adhered Veneer Specification should be updated to include the recommendations of this report and provide the respective recommended testing protocols. The committee will continue to test and evaluate these systems and will update this report as necessary.#

3 encl: July 07, 2008 test results; November 18, 2009 test results; ISO Failure Pattern Chart

CTIOA-TSIB Tensile Pull Test - Stone Tile from Lath, Scratch and Brown Coat Base

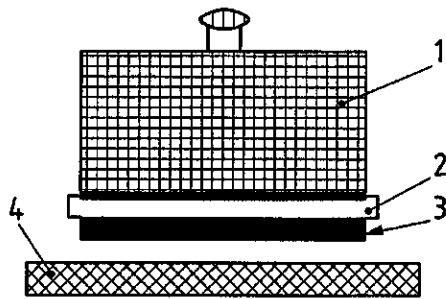
Panel Specifications	Panel #1	Panel #2	Panel #3	Panel #4	Panel #5	Panel #6	Panel #7	Panel #8	Panel #9	Panel #10	Panel #11	Panel #12	Panel #13	Panel #14	Panel #15	Panel #16
Panel Width	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"	18"
Panel Height	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"	23"
Framing Type	A	A	A	A	A	A	B	B	B	B	A	A	A	A	A	A
Framing Spacing	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"	16"
Exterior Sheathing	No	No	No	C	C	C	D	D	D	D	No	No	No	No	No	No
Water-Resistive Building Paper	E	E	E	E	E	E	F	F	F	F	E	E	E	E	E	E
Lath Type	G	G	G	H	H	H	I	I	J	J	G	G	G	G	G	G
Lath Attachment	K	K	K	L	L	L	M	M	M	M	K	K	K	K	K	K
Scratch Coat	N	N	N	N	N	N	N	N	N	N	N-S	P-S	P-T	P-T	PU	PU
Brown (Float) Coat	O	O	O	O	O	O	O	O	O	O	O-S	Q-S	QT	QT	QU	QU
Thin Set Type	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tile Type	V	V	V	V	V	V	V	V	V	V	V*	V	V	V	V	V
Attachment Plate	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Test Results (Failed at PSI)	22.3	20.8	18.5	13.1	18.4	20.8	18.2	11.9	18.4	8.9	50.0	13.7	12.6	11.9	21.1	18.7

- A. 16 gage, 4 inch metal studs
 - B. 2" x 4" wood framing (1 1/2" x 3 1/2")
 - C. 1/2" glass-mat face exterior gypsum sheathing (Dens-Glass)
 - D. 1/2" plywood sheathing exterior sheathing
 - E. 1 - layers of grade "D" water-resistant building paper
 - F. 2 - layers of grade "D" water-resistant building paper
 - G. 3.4 lbs/sy expanded metal flat lath - non-furred
 - H. 3.4 lbs/sy expanded metal self-furred lath
 - I. 1 1/2" x 1 1/2" welded wire with furring points
 - J. 1 1/2" x 17 gage woven wire mesh with furring points
 - K. 8 x 3/4" long self-tapping screw with a 7/16" diameter head
 - L. 8 x 1 1/2" long self-tapping screw with a 7/16" diameter head
 - M. 16 gage wire staple, 15/16" wide crown, 1 1/2" long galvanized
 - N. 1 part portland cement, 1/2 part lime, 3 parts sand
 - O. 1 part portland cement, 1/2 part lime, 4 parts sand
 - P. 1 part riverside common cement, 1/2 part lime, 3 parts sand
 - Q. 1 part riverside common cement, 1/2 part lime, 4 parts sand
 - R. Thinset: Tec Superflex
 - S. Fat mud
 - T. Fat mud with 8510
 - U. Wall float (paragon) out of bag + water
 - V. Tile: 6x6 inch Gascongne Beige Limestone, 3/8" thick - *Panel #11 18 x 18 inch piece tested
 - W. 6" x 6" x 1/4" thick metal plate with a 3/4" diameter hole in the center
- tests started 07.16.08**

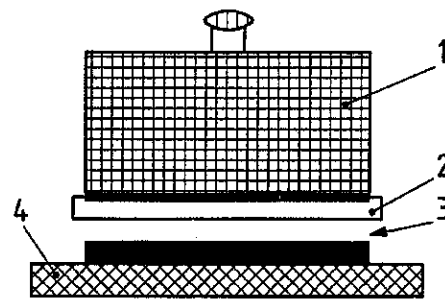
Tensile Pull Test Shear Test

Panel Specifications	Panel - A	Panel - B	Panel - C	Panel - D	Panel - E	Panel - F	Panel - G	Panel - H	Panel - I
Panel Width	18"	18"	18"	18"	18"	18"	18"	18"	18"
Panel Height	23"	23"	23"	23"	23"	23"	23"	23"	23"
Framing Type	A	A	A	B	B	B	A	A	A
Framing Spacing	16"	16"	16"	16"	16"	16"	16"	16"	16"
Exterior Sheathing	No	No	No	No	No	No	No	No	No
Water-Resistive Building Paper	C	C	C	C	C	C	C	C	C
Lath Type	D	D	D	D	D	D	D	D	D
Lath Attachment	E	E	E	E	E	E	E	E	E
Scratch Coat	F	F	F	G	G	G	G	G	G
Brown (Float) Coat	F	F	F	H	H	H	H	H	H
Thin Set Type	I	I	I	I	I	I	I	I	I
Tile Type	J	J	J	J	J	J	J	J	J
Attachment Plate	K	K	K	K	K	K	K	K	K
Test Results (Fractured @PSI)	22.5	16.9	17.2	24.4	17.9	15.1	409.7	350	279.1

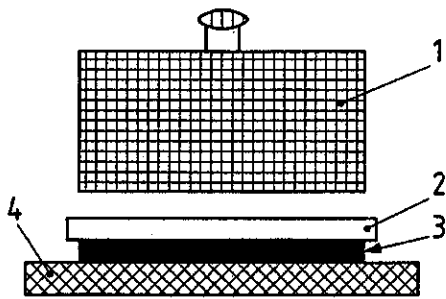
- A. 16 gage, 4 inch metal studs, open cavity
- B. 16 gage, 4-inch metal studs, pulling over a stud
- C. 1 - layers of grade "D" water-resistant building paper
- D. 3.4 lbs/sy expanded metal self-furred lath
- E. 8 x 3/4" long self-tapping screw with a 7/16" diameter head
- F. Quikrete Stucco Base Coat (pump grade) - Silo mix
- G. 1 part portland cement, 1/2 part lime, 3 parts sand
- H. 1 part portland cement, 1/2 part lime, 4 parts sand
- I. Thinset: Tec Superflex
- J. Tile: 6" x 6" x 3/8" thick nominal thickness - Gascoigne Beige Limestone
- K. 6" x 6" x 1/4" thick metal plate with a 3/4" diameter hole in the center



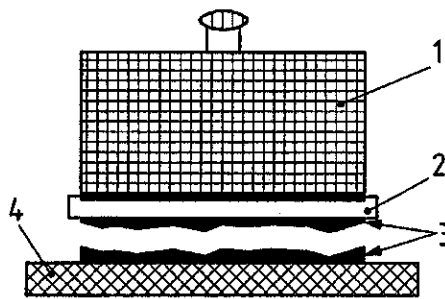
a) Adhesive failure between adhesive and substrate (AF-S)



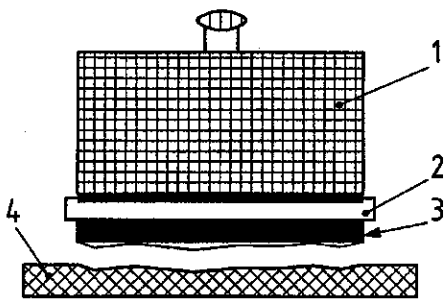
b) Adhesive failure between tile and adhesive (AF-T)



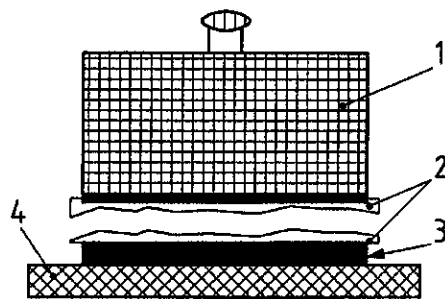
c) Adhesive failure between tile and pullhead plate (BF)



d) Cohesive failure within the adhesive (CF-A)



e) Cohesive failure within the substrate (CF-S)



f) Cohesive failure within the tile (CF-T)

Key

- 1 pull head plate
- 2 tile
- 3 adhesive
- 4 substrate (concrete slab)

3.6 Failure patterns

3.6.1 Adhesion failure (AF-S or AF-T)

Failure occurs at the interface between adhesive and substrate (AF-S) or between tile and adhesive (AF-T). The test value equals the adhesive strength [Figure 3 a) and b)]. In some cases the failure may occur in the adhesive layer between the tile and the pull head plate (BF) [Figure 3 c)]. In this case the adhesive strength is greater than the test value and the test should be repeated.

3.6.2 Cohesive failure within the adhesive (CF-A)

Failure occurs within the adhesive layer [Figure 3 d)].

3.6.3 Cohesive failure in the substrate or in the tile (CF-S or CF-T)

The failure occurs within the substrate (CF-S) [Figure 3 e)] or within the body of the tile (CF-T) [Figure 3 f)]. In this case, the strength of the adhesive is greater than the test value.

The modes of failure may be a combination of any of the above. An approximate percentage of each shall be recorded.