ICC EVALUATION SERVICE

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To: ICC-ES Evaluation Committee

From: Mahmut Ekenel and Russ Krivchuk, ICC-ES Staff

Date: January 28, 2010

Subject: Proposed Acceptance Criteria for Continuous and Semicontinuous Fiber-reinforced Grid Connectors Anchored in Concrete, Subject AC422-0210-R1 (ME/RK)

MEMO

In response to the request for public comments in our December 29, 2009, staff letter on the subject criteria, the following were received:

1. A letter from Thermomass, signed by Venkadesh Seshappa, P.E., dated January 18, 2010.

2. Two letters from the Altus Group, signed by Jason Lien, P.E., each dated January 21, 2010.

ICC-ES staff reviewed these letters and would like to clarify the following issues about the proposed AC422.

1. The reason for development of this criteria is to establish guidelines for the evaluation of shear transfer capacities of continuous or semicontinuous fiber-reinforced grid connectors that are intended to be used in concrete sandwich panels in combination with rigid insulation.

2. The proposed criteria indicates that the criteria is applicable to sandwich panels used as exterior bearing walls to resist gravity loads and wind pressure acting on the panel surface. However, as stated in Section 6.4 of the draft acceptance criteria, use of the grid connector to resist long-term loads is outside the scope of the criteria (and of the evaluation report). Hence, grid connectors cannot be recognized for use as a mechanism to support sustained loads.

3. As stated in the scope of the proposed acceptance criteria (Section 1.2), shear transfer can only be applied parallel to the length of the connector.

4. As stated in the scope of the proposed acceptance criteria (Section 1.2), the connection or connection element is continuous or semicontinuous rather than discrete. Since

AC320 (the Acceptance Criteria for Fiber-reinforced Composite Connectors Anchored in Concrete) is applicable to discrete anchors, AC320 is not applicable to this system. The anchor connector recognized in AC320 is an alternative to concrete anchors as defined in IBC Section 1911, and limited to allowable stress design.

5. Fiber-reinforced grid connectors covered by this acceptance criteria are intended to be used in combination with rigid insulation. As a result, Section 4.2 of the proposed acceptance criteria requires properties of the insulation material to be identified. Insulation material that is used in the tests will be specified in the evaluation report on the grid connectors.

6. As stated in Section 6.7 of the proposed criteria, use of connectors to resist seismic loads is beyond the scope of the evaluation report.

Based on the information given above, attached is a draft of the criteria with the following proposed revisions:

1. Revise the title to “Acceptance Criteria for Continuous or Semicontinuous Fiber-reinforced Grid Connectors Used in Combination with Rigid Insulation in Concrete Sandwich Panel Construction.”

2. Add a new section to Evaluation Report Recognition as follows: “Section 6.8: A statement that lap splicing of continuous fiber connectors is outside the scope of this evaluation report.”

3. Add the following to Section 1.4.3: “type of connector”

4. Revise the first sentence of Section 4.4.1.3 to read: “The connectors are to be tested in multiple rows.”

5. Revise Section 4.4.1.5 to read: “Values for thicknesses that differ from the tested thicknesses can be interpolated from results of other thicknesses provided all other connector design alternatives are the same; however, extrapolation is not acceptable.”

6. Add a new section to Evaluation Report Recognition as follows: “Section 6.9: Statements that special inspection shall apply to the installation of the connectors. Special inspection shall conform to Section 1704 of the IBC.”

7. Delete Section 1.4.3.3 (w_{max}), because AC422 is specific to tested grid connector spacing, concrete type, insulation type and thickness, etc.

8. Revise Section 6.1 to read: “Basic information required by Section 2.1 of this criteria, including product description, installation procedures, packaging, identification and insulation type.”

9. Revise Section 4.3.1 to clarify that the tension tests are tests of the strand (fiber with the polymer matrix) of the connector, not tests of the connector itself.

10. Add a new section to Evaluation Report Recognition as follows: “Section 6.10: Since an ICC-ES acceptance criteria for evaluating the performance of composite connectors in cracked concrete is unavailable at this time, the use of the connectors is limited to installation in uncracked concrete. Cracking occurs when $f_t > f_r$ due to service loads or deformations.”

11. Add a new section to Evaluation Report Recognition as follows: “Section 6.11: Since an ICC-ES acceptance criteria for evaluating data to determine the performance of connectors subjected to fatigue or shock loading is unavailable at this time, the use of these connectors under these conditions is beyond the scope of this report.”

The following editorial corrections are also proposed to the draft of AC422:

1. The correct section number to reference in Section 2.3.1 is Section 4.0, not Section 4.2.

2. The correct section number to reference in Section 2.3.2 is Section 4.1.2, not Section 4.2.

3. Revise section number referenced in Section 6.6 to 4.4, instead of 4.4.2.

4. Revise the definition of “L” in Section 3.3.2 to read: “minimum of 84 inches (2100 mm)” [instead of “minimum length of 7 feet (2.1)”].

5. Revise Section 3.3.3 as follows:

    a. Revise the denominator of equation for G to 4Lw, instead of 2Lw.

    b. Revise the definition of “L” to “minimum of 84 inches (2100 mm),” instead of “minimum length of 7 feet (2.1).”

    c. Revise the definition of “w” to “minimum of 48 inches (1200 mm),” instead of “minimum width of 4 feet (1.2).”

    d. Revise units of measurement of shear modulus to lbs/in^2 (kN/mm^2).

6. Revise the title of Figure 2 to “TYPICAL DOUBLE-SHEAR SPECIMEN.”

7. Revise the title of Figure 3 to “TYPICAL DOUBLE-SHEAR SPECIMEN UNDER LOAD.”

The following are ICC-ES staff comments based on the submitted information:

1. The letter from Thermomass states that the bond between concrete and insulation is broken or weakened over time due to freeze-thaw and temperature cycles. Also, the Thermomass letter states that differential temperature cycling may induce cyclic loading on the connector. Staff seeks input as to whether these issues are valid concerns that need to be addressed in the criteria.

2. The letter from Thermomass raises a question as to whether the length of the connector segments have an effect on the shear flow capacity, staff asks, whether smaller size specimens than the proposed 7-foot-long specimen should be tested, or whether the minimum connecter length specified in the evaluation report should be the 7 feet.

3. The letter from Thermomass raises a question as to whether a strength reduction factor (Ø) must also be addressed in the criteria. In the response received from Altus Group, it is mentioned that the appropriate strength reduction factors are applied during the design of the panels. Since the code and documents referenced by the code do not include strength reduction factors specifically for the panel design, it is the position of the ICC-ES staff that revisions are needed to the criteria to address this issue.

4. The letter from Thermomass raises a question in regard to the effect of elevated temperature on connector anchorage properties during the manufacturing process. With the understanding that the specimens for the tests under the criteria will be assembled consistent with the manner specified by the connector manufacturer and used in production of the sandwich panels, it appears that the issue raised in the Thermomass letter does not need to be addressed in the criteria.

Enclosure: Revised proposed draft criteria.

ICC EVALUATION SERVICE

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PROPOSED ACCEPTANCE CRITERIA FOR CONTINUOUS OR SEMICONTINUOUS FIBER-REINFORCED GRID CONNECTORS ~~ANCHORED IN CONCRETE~~ USED IN COMBINATION WITH RIGID INSULATION IN CONCRETE SANDWICH PANEL CONSTRUCTION

AC422

Proposed January 2010

PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*® reads as follows:

> **The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.**

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria proposed in this document, and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria proposed in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise meet the applicable performance requirements of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

Acceptance criteria are developed for use solely for purposes of issuing ICC-ES evaluation reports.

PROPOSED ACCEPTANCE CRITERIA FOR CONTINUOUS OR SEMICONTINUOUS FIBER-REINFORCED GRID CONNECTORS ~~ANCHORED IN CONCRETE~~ USED IN COMBINATION WITH RIGID INSULATION IN CONCRETE SANDWICH PANEL CONSTRUCTION

1.0 INTRODUCTION

1.1 Purpose: The purpose of this criteria is to provide a procedure for recognition of continuous or semicontinuous fiber-reinforced grid connectors in ICC Evaluation Service, Inc. (ICC-ES), evaluation reports under the 2009 and 2006 *International Building Code*® (IBC) and the 2009 and 2006 *International Residential Code*® (IRC). Bases of recognition are IBC Section 104.11 and IRC Section R104.11.

The reason for development of this criteria is to establish guidelines for the evaluation of shear transfer capacities of the continuous or semicontinuous fiber-reinforced grid connectors, since the codes do not provide requirements for testing and determination of shear transfer capacities of this product.

1.2 Scope: This acceptance criteria is applicable to continuous or semicontinuous fiber-reinforced grid connectors that are combined with rigid insulation to transfer shear stresses in insulated concrete sandwich panels.

The continuous or semicontinuous fiber-reinforced grid connectors addressed by in this criteria, used in conjunction with rigid insulation, are used to provide structural composite action between the panel facers of reinforced concrete sandwich panels that are used as exterior bearing walls to resist gravity loads and wind pressure acting on the panel surface. The grid connectors are factory-cast into the concrete facers of the sandwich panels. The typical shape of the continuous or semicontinuous grid connectors is shown in Figure 1.

The shear transfer capabilities of the fiber-reinforced connection systems and rigid insulation are necessary to achieve composite action between two concrete panels, with the shear transfer parallel to the length of the connector, and the connection or connection element continuous or semicontinuous rather than discrete. Fiber-reinforced grid connectors covered by this acceptance criteria are intended to be used in combination with rigid insulation that is also used to maintain separation of the concrete elements of the sandwich panels. Grid connectors addressed by this criteria are to be used in sandwich panels designed according to ultimate strength design applications. The grid connectors are intended to resist the continuous shear flow induced by composite action between two concrete elements subjected to combined shear and bending in one or more directions.

1.3 Codes and Referenced Standards:

1.3.1.1 2009 *International Building Code*® (2009 IBC), International Code Council.

1.3.2 2009 *International Residential Code*® (2009 IRC), International Code Council.

1.3.3 2006 *International Building Code*® (2006 IBC), International Code Council.

1.3.4 2006 *International Residential Code*® (2006 IRC), International Code Council.

1.3.5 ACI 318-08 (2008), Building Code Requirements for Structural Concrete, American Concrete Institute [2009 IBC].

1.3.6 ACI 318-05 (2005), Building Code Requirements for Structural Concrete, American Concrete Institute [2006 IBC].

1.3.7 ACI 211.1-91 (2002), Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, American Concrete Institute.

1.3.8 ASCE 7-05, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers.

1.3.9 ASTM C 33-03, Standard Specification for Concrete Aggregates, ASTM International.

1.3.10 ASTM C 39-03, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International.

1.3.11 ASTM C 165-07, Standard Test Method for Measuring Compressive Properties of Thermal Insulations, ASTM International.

1.3.12 ASTM C 203-05a, Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation, ASTM International.

1.3.13 ASTM C 303-07, Standard Test Method for Dimensions and Density of Preformed Block and Board-Type Thermal Insulation, ASTM International.

1.3.14 ASTM C 581-03, Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service, ASTM International.

1.3.15 ASTM D 1621-04a, Standard Test Method for Compressive Properties Of Rigid Cellular Plastics, ASTM International.

1.3.16 ASTM D 2247-02, Standard Practice for Testing Water Resistance of Coatings in 100 percent Relative Humidity, ASTM International.

1.3.17 ASTM D 3039/3039M-07, Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials, ASTM International.

1.3.18 ASTM E 488-96 (2003), Standard Test Method for Strength of Anchors in Concrete and Masonry Elements, ASTM International.

1.3.19 EB001 (2002), Design, Control of Concrete Mixtures, 14th edition, Portland Cement Association.

1.4 Definitions:

1.4.1 Continuous Grid Connector: A connector that is continuous for the height of the panel to provide continuous shear transfer capacity between the concrete wythes.

1.4.2 Semicontinuous Grid Connector: Connectors installed in segments such that the connectors are discontinuous along the length of the panel, with maximum separation of 6 inches (152 mm) between the ends of the connector segments.

1.4.3 Connector Design Alternative: The combination of connector grid, insulation type, density and thickness, connector spacing, type of connector, minimum embedment of the connector in the concrete, concrete type and minimum concrete strength that is being tested for recognition.

1.4.3.1 Connector Design: Connector design, determined by connector geometry and connector materials, identified by the manufacturer's catalog number or description.

1.4.3.2 t (Insulation Thickness): Thickness of insulation measured perpendicular to the concrete surfaces that encase the insulation.

~~**1.4.3.3 w_{max} (Maximum Connector Spacing):** Maximum allowable width of unsupported concrete between rows of continuous connectors.~~

1.4.3.3 Minimum Concrete Embedment: Minimum embedment of the connector into each of the two layers of concrete being connected, in order to obtain shear transfer connection between the concrete wythes.

1.4.3.4 Minimum Concrete Strength: The minimum concrete strength for which the connector design alternative is recognized.

1.4.3.5 q_n (Connector Shear Flow): The nominal shear in the continuous connector per unit length of connector.

2.0 BASIC INFORMATION

2.1 Connectors: Description of the connectors shall be submitted and shall include the following:

a. Generic or trade name.
b. Manufacturer’s catalog number.
c. Nominal connector dimensions and geometry.
d. Permitted manufacturing tolerances.
e. Materials.
f. Manufacturing procedure.
g. Manner of field identification.
h. Recommended installation procedures.

2.2 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.3 Test Reports:

2.3.1 Test reports shall comply with AC85, and reports of tests required by Section ~~4.2~~ 4.0 shall include applicable information specified in Section 13 of ASTM E 488 and the following:

a. Mode of failure and location of connector fracture failures for each test specimen.

b. Photographs of test equipment and typical failure.

c. Report of connector sampling at manufacturer's facilities as required by Section 2.4 of this criteria.

2.3.2 **Concrete Properties:** The test reports shall describe the properties of the concrete used in the tests called for by Section ~~4.2~~ 4.1.2 as set forth in Section 4.1 of this criteria.

2.4 **Product Sampling:** Grid connectors and insulation material used in tests shall be sampled in accordance with Section 3.1 of AC85. The manufacturing of the specimens for tests under Section 4.4 shall be witnessed by the testing laboratory.

2.5 **Data Analysis:** The documentation containing analysis of data shall be sealed by a registered design professional.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 **Connector Material Suitability Requirements:** The grid connectors shall be tested in accordance with Section 4.3, and must comply with the requirements of Section 4.3.

3.2 **Connector Performance Tests:** The connector performance tests shall be in accordance with Section 4.4, with the connector design properties determined in accordance with Section 3.3. The concrete used in the connector performance tests shall be tested in accordance with Section 4.1, and comply with the requirements of Section 4.1. The insulation material shall be tested in accordance with Section 4.2, and comply with the requirements of Section 4.2.

3.3 Connector Design Properties:

3.3.1 General: Connectors are intended for design based on ultimate strength design. Information obtained from Section 4.4 of this criteria shall be used to determine nominal shear flow, q_n, and shear modulus, *G,* for each connector design alternative.

3.3.2 Determination of Shear Design Strength: The nominal shear strength shall be calculated using the average ultimate load minus three standard deviations in accordance with the following:

The nominal shear strength, q_n, shall be determined as follows:

$$q_{i,max} = \frac{V_{i,max}}{NL}$$

$$q_{a,max} = \frac{\Sigma q_{i,max}}{n}$$

$$q_n = q_{a,max} - 3\sigma$$

where

$V_{i,max}$ = The peak test load for each test specimen [pounds (kN)].

N = The number of pieces of equal length grid segments in the individual test specimen; minimum of four pieces of grid located concentric to the applied load, as shown in Figure 2.

L = The length of the grid segment and specimen [inches (mm)]; ~~minimum length of 7 feet (2.1)~~ minimum of 84 inches (2100 mm), as shown in Figure 2.

q_n = The nominal shear flow [lbs/in. (kN/mm)].

$q_{a,max}$ = The mean shear flow of the specimens [lbs/in. (kN/mm)].

$q_{i,max}$ = Shear flow for each test specimen [lbs/in. (kN/mm)].

σ = The standard deviation of the peak test load of the test specimens.

n = The number of test specimens.

3.3.3 Determination of Shear Modulus: The shear modulus, *G*, shall be based on deformation measurements of the double shear specimens as shown in Figure 3, and shall be determined at 50 percent of the peak load level as shown in Figure 4.

The shear modulus of the connector, *G*, used to determine the shear component of the deflection of sandwich panels using the grid connector, shall be calculated based on the average nominal shear modulus minus three standard deviations.

The value shall be:

$$G_i = \frac{0.5V_{i,max}}{4Lw} \cdot \frac{t}{\Delta_{i,v}}$$

$$G_a = \frac{\Sigma G_i}{n}$$

$$G = G_a - 3\sigma$$

where:

$V_{i,max}$ = The peak test load for each specimen [pounds (kN)].

G_i = Shear modulus for each test specimen [lbs/in^2. (kN/mm^2)].

G_a = The mean shear modulus of the test specimen [lbs/in^2. (kN/mm^2)].

t = Thickness of the rigid foam insulation [inch (mm)].

L = The length of the grid segment and specimen [inch (mm)]; ~~minimum length of 7 feet (2.1)~~ minimum of 84 inches (2100 mm), as shown in Figure 2.

w = The width of the specimen [inch (mm)]; ~~minimum width of 4 feet (1.2)~~, minimum of 48 inches (1200 mm), as shown in Figure 2.

$\Delta_{i,V}$ = Relative displacement between the core material and the two outer wythes of each specimen evaluated at 50 percent of the peak load level, as shown in Figure 3 [inch (mm)].

σ = The standard deviation of the shear modulus of the test specimens.

4.0 TEST METHODS AND ANALYSIS

4.1 Concrete:

4.1.1 Concrete Mix

4.1.1.1 The type of concrete shall be same as the concrete that is intended to be used in the sandwich panel construction.

4.1.1.2 Concrete mix design shall follow recommendations for proportioning in EB001, ACI 211.1 or IBC Chapter 19 (ACI 318). Proportions may be varied to meet local requirements and to achieve desired nominal compressive strength. The reason for any variation shall be explained in the test report.

4.1.1.3 Coarse and fine aggregate in concrete shall comply with ASTM C 33 for normal-weight concrete. The aggregate description shall include the rock and mineral components, shape, hardness, maximum size, and grading specification.

4.1.1.4 Concrete test cylinders shall be prepared, stored and cured according to ASTM C 31 (field cure). Concrete cylinders shall be tested in accordance with ASTM C 39 and Section 4.1.2 of this criteria, to determine the strength of the concrete of the specimens of tests under Section 4.4.

4.1.1.5 Reinforcement may only be used to stabilize test members during transportation. Reinforcing elements in concrete test members shall be outside the potential failure region of each test connector or connector group. The testing laboratory shall verify location of reinforcing.

4.1.2 Concrete Strength Determination:

4.1.2.1 Concrete test members shall be aged a minimum of 21 days prior to the beginning of connector tests.

4.1.2.2 For concrete less than 90 days old, two tests of two cylinders each, prepared according to Section 4.1.1 of this criteria, shall be performed at the beginning and ending of connector testing. The beginning test shall be concurrent with the initiation of connector testing. The beginning and ending strength results shall be averaged (four cylinders) to establish the strength of the test members during the connector test period.

4.1.2.3 For concrete aged 90 days or more, the compressive strength shall be the average of the results for a single test of three cylinders determined after at least 90 days and within 30 days of connector testing.

4.1.2.4 Reported concrete strength for any connector test series shall be determined from the tests in this section.

4.2 Insulation Material: The following properties of the insulation used in the connector performance test specimens shall be reported:

- Compressive strength (ASTM C 165).
- Flexural strength (ASTM C 203).
- Density (ASTM C 303).
- Compressive properties of rigid cellular plastics (ASTM D 1621), if applicable.

4.3 Material Suitability Requirements of Fiber-reinforced Grid Connectors

4.3.1 Tensile Properties: Ultimate tensile strength, ultimate tensile strain and tensile modulus of elasticity of the strand of the connector grid shall be determined in accordance with ASTM D 3039. The specimens shall be cut from the manufactured grid connectors. Twenty specimens shall be tested. Specimen sets shall exhibit a coefficient of variation (COV) of 6 percent or less. Outliers are subject to further investigation according to ASTM E 178. If the COV exceeds 6 percent, the number of specimens shall be doubled. Gripping shall be such that it does not damage the specimen and cause premature failure of the specimen in the gripping location. Tensile properties shall be reported.

4.3.2 Environmental Properties: The fiber-reinforced grid connector material's response to moisture, wet concrete environment, and aging shall be determined as follows:

4.3.2.1 Effects of Moisture and Aging: Testing shall be conducted in accordance with ASTM D 2247, Section 7. Tensile strength testing of the material, conducted in accordance with Section 4.3.1 of this criteria, shall be determined after exposure of the material to 100 percent humidity at 100 ± 4^{o}F (37 ± 2^{o}C) for 1,000 and 3,000 hours. Twenty specimens shall be tested.

4.3.2.2 Effects of Wet Concrete Environment and Aging: Testing shall be conducted in accordance with ASTM C 581, Section 7.2. Tensile strength testing of the material, conducted in accordance with Section 4.3.1 of this criteria, shall be determined after the material has been exposed to an alkali solution with a pH of 12 at 73 ± 3^{o}F (23 ± 1.6^{o}C) for 1,000 and 3,000 hours. Twenty specimens shall be tested.

4.3.2.3 The conditions of acceptance for environmental properties evaluated under Sections 4.3.2.1 and 4.3.2.2 of this criteria are shown in Table 1.

4.4 Connector Performance Tests

4.4.1 Connector Installation:

4.4.1.1 Each grid connector design alternative to be recognized shall be tested.

4.4.1.2 The grid connectors shall be installed into concrete of the test members in accordance with the grid manufacturer's recommendations. The manufacturing of the specimens for tests shall be witnessed by a representative of the testing laboratory. Pertinent data such as connector embedment, spacing, thickness of attached and receiving materials, etc., shall be observed and reported by the testing laboratory representative.

4.4.1.3 The connectors are to be ~~may be~~ tested in ~~single rows or~~ multiple rows. Multiple rows shall be parallel and uniformly spaced. The connector length shall be the same as the length of the concrete elements. The rigid insulation shall extend the full length and width of the concrete elements. The width of rigid insulation associated with each connector row shall be the recognized value.

4.4.1.4 Concrete embedment of the connectors shall be the minimum recommended by the grid connector manufacturer. Thickness of the concrete element shall be the minimum recommended by the grid connector manufacturer for at least one of the concrete elements in the assembly.

4.4.1.5 ~~Results for thicknesses that differ from the tested thicknesses can be interpolated for results of other thicknesses; however, extrapolation is not acceptable.~~ Values for thicknesses that differ from the tested thicknesses can be interpolated from results of other thicknesses provided all other connector design alternatives are the same; however, extrapolation is not acceptable.

4.4.2 Connector Shear Tests: Shear tests shall be performed with push-through specimens consisting of three layers of concrete and two layers of rigid insulation with connectors as seen in Figure 2. The test shall consist of loading the center layer and supporting the outer two layers. Load shall be applied parallel to the connector rows and concentric to the test specimen. Test specimens, supports, and loading shall all be symmetric about the center plane of the test specimen. Measurements shall include applied load and deflection of the center layer of concrete relative to the outer two layers. Five specimens shall be tested for each combination. The relative displacement at supports should be prevented using frictionless lateral support. Loading rate shall be 0.05 inch/minute (1.30 mm/minute).

4.4.3 Test Equipment: Test equipment for shear loading shall be adequate to impose the anticipated ultimate loads and shall comply with Section 5.1.1 of ASTM E 488. If loading is not carried to failure, the highest load achieved shall be considered the ultimate load.

5.0 QUALITY CONTROL

5.1 The connector grids shall be manufactured under an approved quality program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or otherwise acceptable to ICC-ES. The quality program shall verify continued connector compliance with specifications in Section 2.1.

5.2 Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted.

6.0 EVALUATION REPORT AND RECOGNITION

The evaluation report shall include the following:

6.1 Basic information required by Section 2.1 of this criteria, including product description, installation procedures, packaging, ~~and~~ identification and insulation type.

6.2 Nominal shear flow capacity and shear modulus for each connector design alternative, as determined by Section 3.3 of this criteria.

6.3 A statement that connectors are not recognized for use in conjunction with fire-resistance-rated construction.

6.4 A statement that use of the connector to resist long-term loads is outside the scope of the evaluation report.

6.5 A statement that connectors are for use in concrete sandwich panels recognized in a current ICC-ES evaluation report, or are for use in concrete sandwich panels where compliance with the codes has been demonstrated to the satisfaction of the code official.

6.6 A statement that qualification testing, as described in Section ~~4.4.2~~ 4.4 of this criteria, is needed for each sandwich panel manufacturing facility. The testing must justify that the nominal shear flow capacity and shear modulus of the grid connectors is applicable to the sandwich panels manufactured at that panel manufacturing facility.

6.7 A statement that use of connectors to resist seismic loads is beyond the scope of the evaluation report.

6.8 A statement that lap splicing of continuous fiber connectors is outside the scope of this evaluation report.

6.9 Statements that special inspection shall apply to the installation of the connectors. Special inspection shall conform to Section 1704 of the IBC.

6.10 Since an ICC-ES acceptance criteria for evaluating the performance of composite connectors in cracked concrete is unavailable at this time, the use of the connectors is limited to installation in uncracked concrete. Cracking occurs when ft > fr due to service loads or deformations."

6.11 Since an ICC-ES acceptance criteria for evaluating data to determine the performance of connectors subjected to fatigue or shock loading is unavailable at this time, the use of these connectors under these conditions is beyond the scope of this report.

TABLE 1—ENVIRONMENTAL DURABILITY TEST MATRIX

ENVIRONMENTAL DURABILITY TEST	RELEVANT SPECIFICATIONS	TEST CONDITIONS	TEST DURATION	MINIMUM NUMBER OF SPECIMENS	PERCENT RETENTION OF AVERAGE TENSILE STRENGTH	
					1,000 Hours	3,000 Hours
Water resistance	ASTM D 2247	100 percent, 100 ± 4°F	1,000 and 3,000 hours	20 for each duration	90	85
Alkali resistance	ASTM C 581	Immersion in alkali solution of pH = 12 at 73 ± 3°F	1,000 and 3,000 hours	20 for each duration		

For **SI:** 1°C = 5/9(t°F - 32).

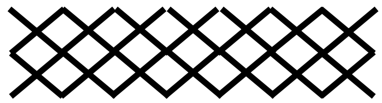


FIGURE 1 — TYPICAL C-GRID CONNECTOR

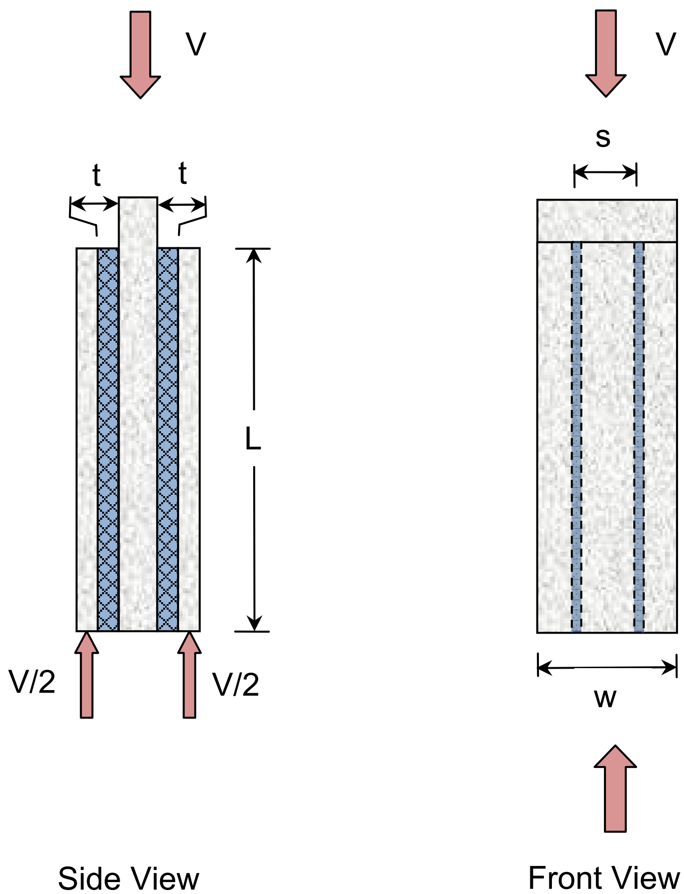
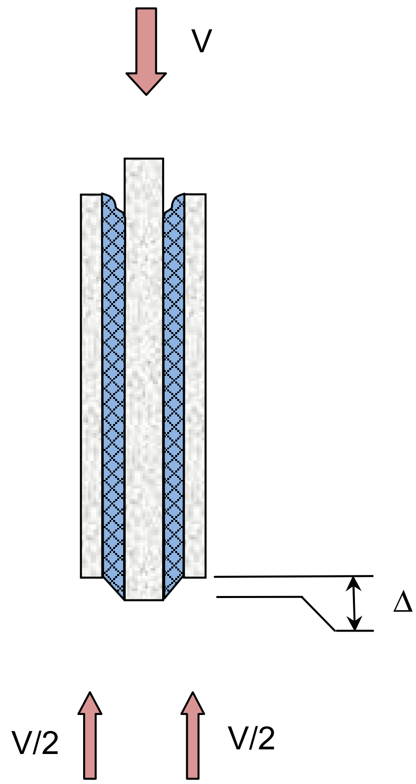


FIGURE 2 — TYPICAL ~~DOBLE~~ DOUBLE-SHEAR SPECIMEN



Side View

FIGURE 3 — TYPICAL DOUBLE-SHEAR SPECIMEN ~~SPECIMAN~~ UNDER LOAD

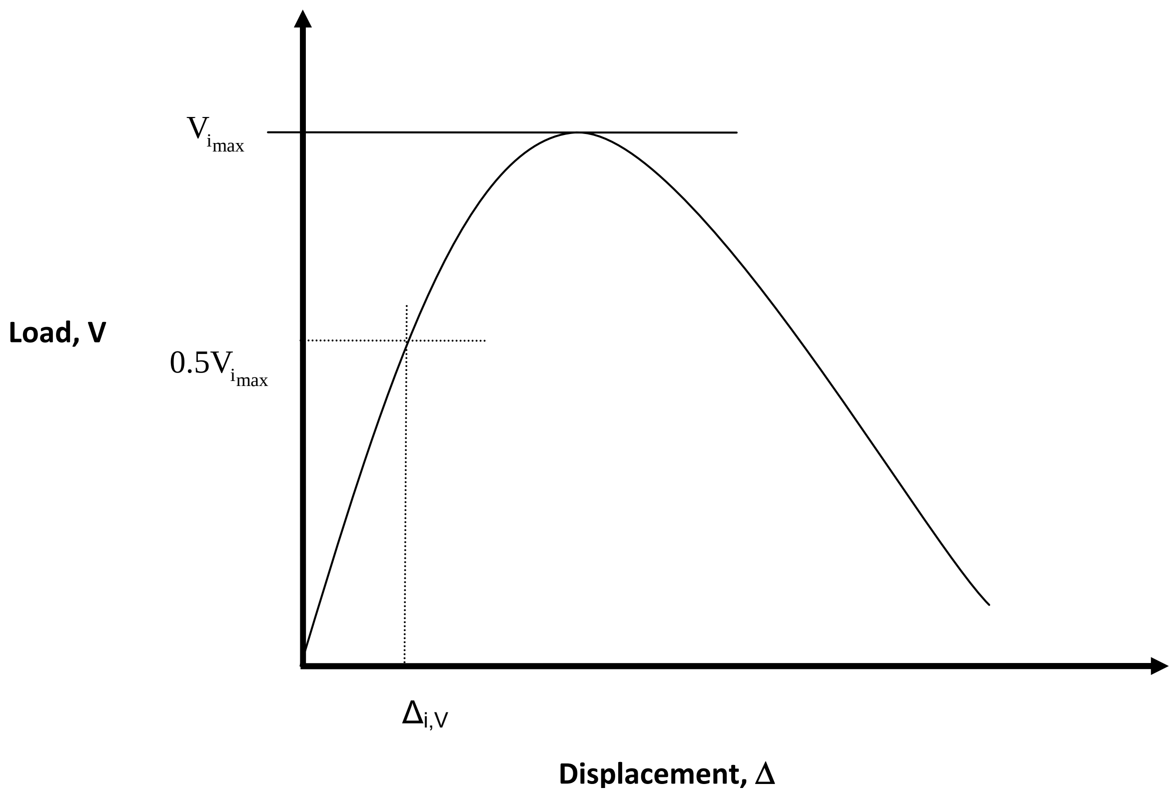


FIGURE 4 — REPRESENTATIVE LOAD vs. DISPLACEMENT GRAPH