ICC EVALUATION SERVICE

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MEMO

To: ICC-ES Evaluation Committee

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

Date: June 10, 2010

Subject: Proposed Acceptance Criteria for Continuous and Semicontinuous Fiber-reinforced Grid Connectors Used in Combination with Rigid Insulation in Concrete Sandwich Panel Construction, Subject AC422-0610-R2 (ME/RK)

In response to the request for public comments in our May 13, 2010, staff letter on the subject criteria, the following were received:

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

2. A letter from the Altus Group, signed by Jason Lien, P.E., dated June 1, 2010.

The following are ICC-ES staff comments after review of the submitted materials:

1. This comment is related to item no. 1 of the staff letter dated May 13, 2010. It is staff opinion that due to the test configuration in Figure 3 of the draft criteria, a shorter height may adversely affect test results, resulting in lower design values. Therefore, staff recommends that a condition of use be added to Section 6.0 of the criteria limiting the end use of the product to panels with a minimum span of 7 feet, as follows: <u>The minimum span of panels with fiber-reinforced grid connectors is limited to 7 feet</u>.

2. This comment is related to item no. 2 of the staff letter dated May 13, 2010. Staff acknowledges the test reports mentioned by Altus Group in their letter dated June 1, 2010. However, the full reports of tests were not presented for ICC-ES and public review. The letter from Thermomass, dated June 1, 2010, states that cyclic loading may adversely affect the bond between the concrete and insulation material, and therefore may affect shear flow capacity. Staff's opinion is that a revision is needed to the criteria to include a test procedure and conditions of acceptance to evaluate the effect of cyclic loading on the bond between concrete and insulation.

   In addition, no response has been received in regard to the effect of freeze-thaw cycling on the durability of the bond between the concrete and insulation material. This requires further investigation.

3. This comment is related to item no. 3 of the staff letter dated May 13, 2010. Consistent with item no. 3 of the Altus Group letter dated June 1, 2010, staff acknowledges that the source of the strength reduction factors, given in Section 3.4.1 of the proposed draft acceptance criteria, are from ACI 318 and ACI 440. Staff is aware of an additional strength reduction factor (Ψ_f) of 0.85 for shear as stated in Section 11.3 and Table 11.1 of ACI 440. Staff's position is that this additional strength reduction factor of Ψ_f needs to be included in Section 3.4.1 (1) of the criteria as a multiplier to the value of Ø.

4. This comment is related to item no. 4 of the staff letter dated May 13, 2010. Staff supports the recommendation of the Altus Group to delete Section 3.4.2. The evaluation report published in accordance with this criteria will only report shear flow capacity and shear modulus.

5. This comment is related to item no. 5 of the staff letter dated May 13, 2010. Staff does not concur with the Altus Group request to delete creep effects from the criteria. The criteria currently addresses creep effects on strength and stiffness in Sections 3.4.1(2) and 3.4.3, respectively.

6. This comment is related to item no. 6 of the staff letter dated May 13, 2010. Staff acknowledges item no. 3 of the Thermomass letter, dated June 1, 2010, which states that the test, as currently described in Figure 2 of the proposed criteria, will tell us the behavior of neither continuous grid nor semicontinuous grid. Staff shares this concern and questions the purpose of testing of the specimen containing a combination of continuous and semicontinuous grids. It is the ICC-ES staff recommendation that Figure 3 be revised to indicate continuous grids only.

7. This comment is related to item no. 7 of the staff letter dated May 13, 2010. In accordance with the Altus Group letter item no. 7, staff supports removing tension evaluation by deletion of Sections 1.4.3.6 and 3.4.2.

8. Item No. 1 of the letter sent by the Altus Group, dated June 1, 2010, states that the physical grid specimens are produced in lengths of 66 inches. However, 7-foot-long specimens were proposed to be tested in the criteria (84 inches). We are questioning how a continuous grid system can be achieved in an 84-inch-long test specimen, if the maximum grid length is 66 inches. Staff also questions how a continuous grid system is constructed in the panel, if panel length exceeds 66 inches?

9. The letter from Thermomass, item no. 4, 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 in 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. However, staff proposes to amend the last sentence of Section 4.4.1.2 as follows: "Pertinent data such as connector embedment, spacing, thickness of attached and receiving materials, manufacturing procedure, etc., shall be observed and reported by the testing laboratory representative."

10. Staff proposes an amendment to Section 4.2 by adding the following sentence: Insulation material shall be recognized in a current ICC-ES evaluation report.

11. The Thermomass letter dated June 1, 2010, raises a question in regard to cracked versus uncracked concrete. Staff's opinion is that Sections 6.11 and 6.7 address this concern.

12. Staff proposes revisions to Figure 2 of the draft criteria with the addition of L = 84 inches and w = 48 inches.

The additional revisions proposed by the ICC-ES staff are shown in the attached revised criteria.

Enclosure: Revised proposed draft criteria.

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

AC422

Proposed May 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 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 *International Building Code*® (IBC) and the 2009 *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 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 walls to resist wind pressure acting on the panel surface. This acceptance criteria also addresses connectors used to transfer shear forces between the concrete panel facers due to gravity loads on sandwich panels used as exterior bearing walls. 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 addressed by the acceptance criteria are for shear transfer parallel to the length of the connector, with the connection or connection element continuous or semicontinuous rather than discrete. The grid connectors are intended to transfer the shear flow induced by composite action between two concrete elements subjected to flexural bending in one or more directions. Grid connectors addressed by this criteria are to be used in sandwich panels designed according to ultimate strength design applications.

1.3 Codes and Referenced Standards:

1.3.1 2009 *International Building Code*® (2009 IBC), International Code Council.

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

1.3.3 ACI 318-08 (2008), Building Code Requirements for Structural Concrete, American Concrete Institute.

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

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

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

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

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

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

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

1.3.11 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.

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

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

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

1.3.15 ASTM E 119-07, Standard Test Methods for Fire Tests of Building Construction and Materials, ASTM International.

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

1.3.17 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 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.

~~**1.4.3.6 t_n - Connector tension per unit length:** The nominal tensile strength 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 4.0 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 connector performance tests called for by Section 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 specified in 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 q_n and G determined in accordance with Section 3.3. The concrete used in the connector performance tests shall be tested in accordance with Section 4.1 to establish the concrete type and compressive strength requirements for end-use conditions. The insulation material of the connector performance test specimens shall be tested in accordance with Section 4.2 to establish the required physical properties of the insulation material to be specified for end-use conditions.

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 procedures:

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 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 in accordance with the following procedures:

$$G_i = \frac{0.5V_{i,max}}{A_{sa}} \cdot \frac{t}{\Delta_{i,v}} = \frac{0.5V_{i,max}}{2Lw} \cdot \frac{t}{\Delta_{i,v}}$$

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

$$G = G_a - 3\sigma$$

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 of 84 inches (2100 mm), as shown in Figure 2.
A_{sa}	=	the total contact surface area between the insulation material and both surfaces of the central concrete wythe [$inch^2$ (mm^2)].
w	=	the width of the specimen [inch (mm)]; minimum of 48 inches (1200 mm), as shown in Figure 2.
$\Delta_{i,V}$	=	relative displacement between the central concrete core and the two outer concrete wythes of each specimen evaluated at 50 percent of the peak load level, as shown in Figure 3 [inch (mm)].
σ	=	standard deviation of the shear modulus of the five test specimens.

3.4 Design Parameters

3.4.1 Strength Reduction Factors: The following strength reduction factors are applicable for the design of the standard panels:

1) A strength reduction factors of 0.75 shall be used to determine the nominal design shear flow strength. An additional strength reduction of factor of 0.85 (Ψ_f) shall also be applied to improve the reliability of strength prediction: $\phi\psi_f q_n = 0.75 \times 0.85 \times q_n$ ~~$\phi q_n = 0.75 q_n$~~

2) For the design of the sandwich panels for sustained loads, a strength reduction factor of 0.15 shall be used to determine the nominal design shear flow strength: $\phi q_n = 0.15 q_n$

~~**3.4.2 Combined Loading:** Combined loading does not need to be considered unless the ultimate applied tension on the grid, t_u exceeds 20 percent of Nominal Design Tension per Unit Length Strength, ϕt_n, where:~~

~~$t_n = 107.0 \frac{\text{kip}}{\text{in}}$~~

~~$\phi = 0.75$~~

3.4.3 Stiffness: Designing the deflections of sandwich panels using the construction method under consideration shall be based on the combination of flexural deformation and shear deformation. The total deformation shall be based on the following

$$(\delta_F \lambda_\Delta + \delta_S \xi) = \delta_{LongTerm}$$

Where;

δ_F = the flexural deflection of the panel due to moment applied to the panels by sustained gravity loads

λ_{Δ} = long term flexural deformation creep factor due to sustained loads as defined in Section 3.4.3.1

δ_S = the shear deflection of the panel due to shear in the panel due to the sustained gravity loads

ξ□ = Shear deformation creep factor due to sustained loads as defined in Section 3.4.3.2

3.4.3.1 Flexural Deformations: Long term load flexural deformation calculations shall follow any rational method. The long term load modification factor is defined as λ_{Δ} in accordance with ACI 318 Section 9.5.

3.4.3.2 Shear Deformations: Long term load shear deformation calculations shall follow any rational method. The long term modification factor is defined as ξ in accordance with ACI 318 Section 9.5.

4.0 TEST METHODS AND ANALYSIS

4.1 Concrete: The concrete used in the connector performance tests must be evaluated in accordance with the following:

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 the connector performance 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 performance testing. The beginning and ending strength results shall be averaged (four cylinders) to establish the strength of the test members during the connector performance 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 performance test series shall be determined from the tests in this section.

4.2 Insulation Material: Insulation material shall be recognized in a current ICC-ES evaluation report. 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 material 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 of the test specimens 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 conducted after exposure of the material to 100 percent humidity at 100 ± 4°F (37 ± 2°C) for 1,000 and 3,000 hours. Twenty specimens shall be tested at each time increment.

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°F (23 ± 1.6°C) for 1,000 and 3,000 hours. Twenty specimens shall be tested at each time increment.

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 General:

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, manufacturing procedure, etc., shall be observed and reported by the testing laboratory representative.

4.4.1.3 The connectors are to be tested in 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.

4.4.1.5 Test result values for concrete 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.

~~The test specimen shall contain at least one row of semicontinuous grid connector material. Should there be two rows of semicontinuous grid connector material the gaps between rows will be spaced no closer than 18 inches (457 mm) measured in the direction of *L* as shown in Figure 2. There shall be no more than one gap per row of semicontinuous grid connector material.~~

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 all 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.

4.5 Fire Resistance (Optional): Recognition of connector use in fire-resistive construction shall be evaluated for load resistance during fire exposure. General guidelines for fire exposure testing are in ASTM E 119.

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, identification and insulation type.

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

6.3 A statement that the strength reduction factors to be used in design shall be consistent with those specified in Section 3.4.

6.4 A statement that connectors are not recognized for use in conjunction with fire-resistance-rated construction, if test reports in accordance with Section 4.5 are not submitted.

6.5 A statement that connectors are for use in concrete sandwich panels recognized in a current ICC-ES evaluation report.

6.6 A statement that qualification testing, as described in Section 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 short-term loads due to product manufacturing, transportation, and handling is outside the scope of this criteria.

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

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

6.11 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.

6.12 A statement that because ~~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.

6.13 A statement that the minimum span of panels with fiber-reinforced grid connectors is limited to 7 feet.

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).

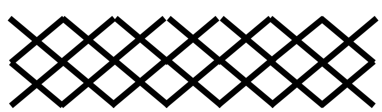

FIGURE 1 — TYPICAL C-GRID CONNECTOR

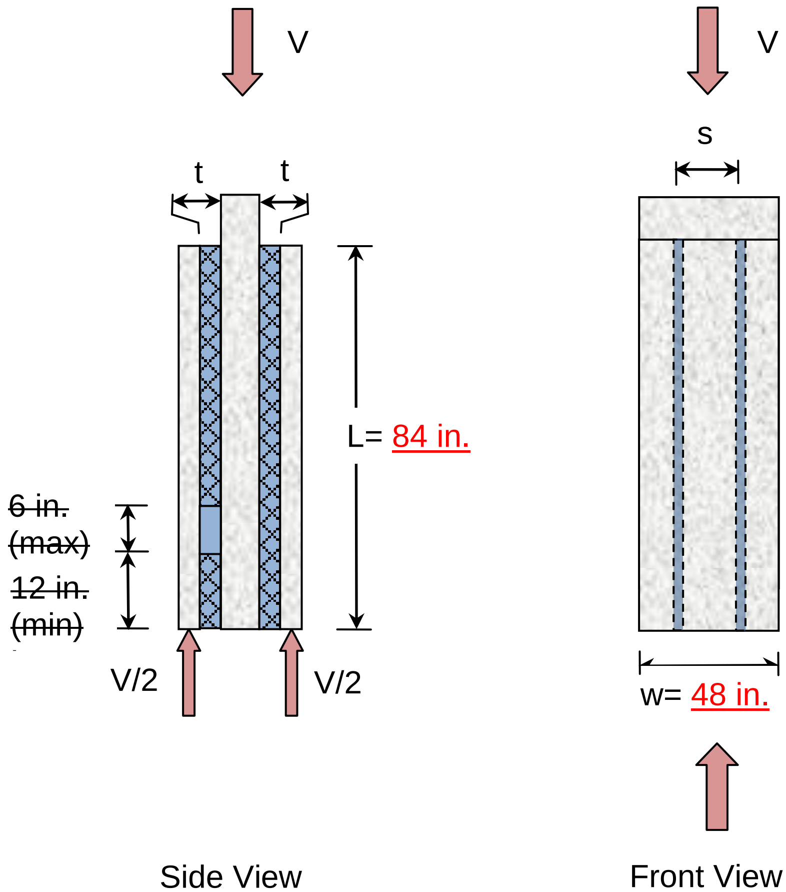

FIGURE 2 — TYPICAL DOUBLE-SHEAR SPECIMEN

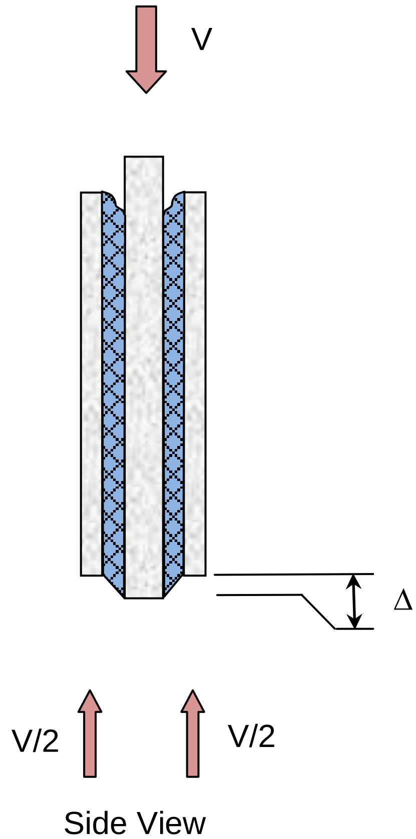

FIGURE 3 — TYPICAL DOUBLE-SHEAR SPECIMEN UNDER LOAD

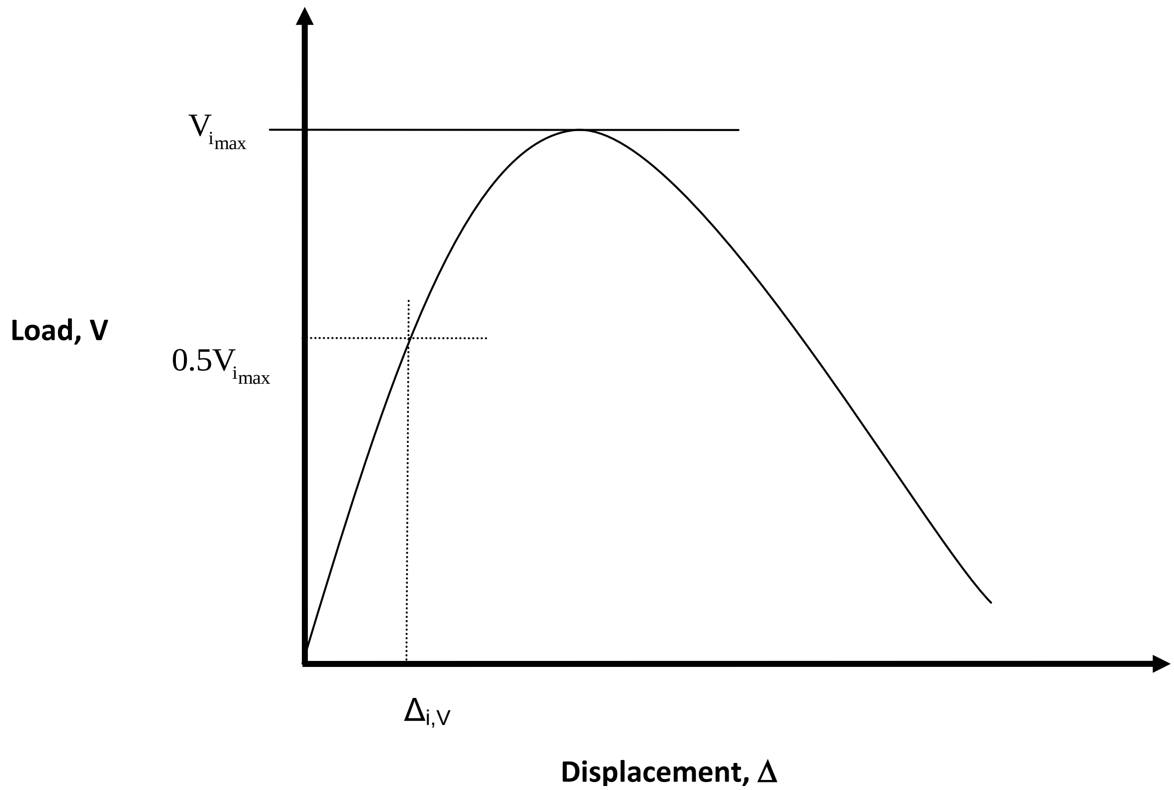

FIGURE 4 — REPRESENTATIVE LOAD vs. DISPLACEMENT GRAPH