THERMOMASS®
BUILDING INSULATION SYSTEMS
By Composite Technologies Corporation

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Ref: Proposed Acceptance Criteria, AC422-0210-R1

Dear Sir,

As a licensed professional engineer, a member of PCI's Sandwich Wall Panel committee, a member of ACI's Precast Panels, (ACI 533) committee, a member of PCI's Fiber Reinforced Polymer committee, and as the Director of Engineering at Composite Technologies Corporation, a company that manufactures fiber composite wythe connector for sandwich wall, similar to one for which AC422 is being developed, I have concerns that the proposed acceptance criteria AC422 does not cover all the tests required for the evaluation of such a product. Additionally, it is unclear if AC422 is being developed for the use of fiber-reinforced grid connectors anchored in concrete alone or as a system combining insulation and fiber-reinforced grid connectors for use in sandwich wall panels. If AC422 is developed for the connectors alone, I bring to your attention the approved Acceptance Criteria, AC320 which was developed for fiber-reinforced composite connectors anchored in concrete similar to fiber-reinforced grid connectors. Since both connectors are used in the production of insulated wall panels, they experience similar handling, erection, and in-service loads, I strongly feel that AC 320 should be applicable for fiber-reinforced grid connectors with some modifications to AC320 if needed. If it is determined that a new acceptance criteria (AC422) is needed, then at a minimum, all the tests and other criteria required in AC320 should be required of AC422. In this letter, I emphasize the criteria and tests that I think are required to fully evaluate the fiber-reinforced grid for use in insulated sandwich wall panels.

1. Insulated wall panels are subjected to tension, shear, and bending loads and therefore, an interaction equation is required for combined loads in AC422. See section 3.3.4 of AC320 as an example.
2. In the scope of AC422 (line 17), it states that this type of connector will be used in exterior load bearing walls to resist gravity loads. However, in section 6.4 (line 301-302), the proposed criteria states that the use of connector to resist long-term loads is outside the scope of the evaluation report. This to me is in direct contradiction of line 17.
3. It is unclear if AC422 is developed for the fiber-reinforced grid connectors alone or as a system of insulation and grid connectors together for use in the sandwich wall panel. Lines 21 and 22 state that the connectors and rigid insulation are necessary to achieve composite action

between the two concrete wythes. If AC422 is developed for grid connectors alone, then all the shear tests should be conducted without insulation in between the concrete wythes. Otherwise, the title of AC422 should be revised to reflect the system rather than the connector.

4. Lines 29 and 30 of the proposed criteria state that the connectors are intended to resist the continuous shear flow induced by composite action. It is known in the industry that certain types of insulation (i.e. expanded polystyrene) provide better bond with concrete thereby increasing the initial shear capacity of the system. Similarly, certain types of insulation (i.e. extruded polystyrene and faced polyisocyanurate) have very little or no bond. It is known in the industry that the bond between the concrete and insulation is broken or weakened over time due to freeze thaw and temperature cycles. Hence if AC422 is developed for connectors only, all tests should be conducted with the bond broken between insulation and concrete. If AC422 is for the system, there should be a requirement that the insulation used in the evaluation process and in construction to have an Evaluation Service Report (ESR) to ensure that the quality of insulation is consistent with the connector.
5. Lines 29, 30, and 31 of proposed criteria addresses the shear flow induced by composite action due to combined shear and bending in one or more directions. However, the proposed AC only requires shear tests in strong direction of the connector while shear tests in the weak direction are not required. This should be a requirement in AC422 as without the weak axis shear tests, one cannot calculate the bending capacity in the weak direction.
6. Also, sandwich panels are typically used as spandrel panels (horizontal dimension larger than vertical dimension) in buildings. In such panels, the shear resistance due to bending is required in horizontal direction (longer direction) and shear resistance is required in vertical direction since the fascia wythe is supported by the connector, which means the connector is subjected to shear in weak direction. Another reason for requiring weak axis shear test. See Figure 1.
7. Furthermore, sandwich panels are often stored and transported vertically without the equal wythe support. This imparts shear load in the weak direction in the connector. Yet another reason for conducting the weak axis shear test. See Figure 2.
8. In lines 73-75, a definition of Continuous Grid Connector is given. It is my understanding that the fiber reinforced grid is manufactured in 8 foot wide roll or sheets where the grids are perpendicular and then the connectors are cut to the required width at 45°. This means the longest connector length would be around 11'-4". See Figure 3. If the panels are greater than 11'-4", the two or more connectors must be lapped to be defined as a continuous grid connector. The definition 1.4.1 should include this lap length and some test should be conducted that this lap length is adequate to develop the full tensile strength of the connector.
9. In lines 76-78, a definition of semi-continuous connector is given. I believe the length of the connector segments do have an effect on the shear flow capacity. Hence, smaller size specimens than the proposed 7-ft x 4-ft specimen should be tested or a minimum connector length of 7-ft should be added to the semi-continuous connector definition.

10. In lines 79-82, definition 1.4.3 should include the type of connector, whether it is continuous or semi-continuous in the Connector Design Alternative as the shear flow will be different between the continuous and semi-continuous connector.
11. In line 102, the perpendicular grid spacing dimension of the connector should be required.
12. Lines 113 and 121 reference Section 4.2 for tests; however, the section 4.2 is about insulation material.
13. Line 139 states that the connectors are intended for design based on ultimate strength design. However, AC422 does not specify the "phi" (strength reduction) factors to use in the design. It is unclear if one is supposed to use "phi" factor in addition to the shear design strength as determined per section 3.3.2. It is my strong opinion that strength reduction factor of 0.5 should be included in section 3.3. The reasoning is as follows :

$$COV = \frac{\sigma}{q_{a,max}}$$

Assuming a coefficient of variation (COV) of 6% (note that COV for shear tests are not given in section 3.3 or section 4), $\sigma = 0.06 * q_{a,max}$. If we substitute this σ in line 148, we get

$$q_n = 0.82 * q_{a,max}$$

I strongly disagree that shear design strength should be such a high percentage of mean test value especially when only five specimens are tested. With a live load factor of 1.6, the approximate factor of safety using equation on line 148 is only 1.95. Typically, in the precast industry, the connections are designed to a factor of safety of 4. Now, if we multiply q_n by $\varphi = 0.5$, then factor of safety will be approximately 3.9, which I believe is appropriate for wall panels designed with brittle connectors. Note that if the COV is less than 6%, or the load factor is less than 1.6, then the factor of safety will be lower.

14. Line 155 shows the minimum length of connector as feet and meters. This needs to be changed to inches and millimeters to be consistent with line 154.
15. In line 170, I think the factor of safety is not adequate for shear modulus for the reasons explained above in item 13.
16. In line 168, I think the denominator should be "4Lw" since there will be 4 grid connectors in each specimen evaluated at half of peak load.
17. In line 174, the units for shear modulus should be lbs/in^2 or kN/mm^2 based on the equation on line 168.
18. Line 177 shows the minimum length of connector as feet and meters. This needs to be changed to inches and millimeters to be consistent with line 176.
19. Sandwich walls are used as exterior walls and are subjected to differential temperature several times during year. This induces cyclic loading on the connector. Therefore, connectors should be tested for cyclic tension and cyclic shear. We recommend a minimum of 100 cycles at 40% of

deflection expected for 40°F temperature differential between the interior face and exterior face. Another 30 cycles at 60% deflection and 10 cycles at 100% deflection. In lieu of cyclic test for temperature, more rigorous cyclic tests for seismic loading as required per AC320 can be required in AC422.

20. Sandwich panels are often steam cured in the manufacturing facility where the temperature of the concrete element can approach 150°F to 180°F. Connector anchorage properties at an elevated temperature of 150°F should be evaluated.
21. Since AC422 is developed for load bearing walls, long term creep test should be required in AC422 similar to AC320.
22. Section 4.3.1 requires ultimate tensile strength per ASTM D3039. However, the scope of ASTM D3039 is as follows "This test method determines the in-plane tensile properties of polymer matrix composite materials reinforced by high-modulus fibers. The composite material forms are limited to continuous fiber or discontinuous fiber-reinforced composites in which the laminate is balanced and symmetric with respect to the test direction." I believe that grid connector is out of the scope of ASTM D3039. New test procedures should be developed for the grid connector.
23. Also, section 4.3.1 does not define the direction in which the connector grid to be tested. As explained earlier, the grid connector is cut from perpendicular grid, and section 4.3.1 should define the tensile test is to be done at 45° to the grid, which will be along the length of the grid connector. See Figure 4.
24. Furthermore, section 4.3.1 should define the gage length of test specimen since the ASTM D3039 would not be applicable for grid connectors.
25. In general, section 4.4 is not clear. Similar to section 4.3, the test method used in this section should be identified. Assuming that the test method ASTM E 488 will be used to determine the shear flow and shear modulus, I recommend that suitable modifications to the test procedure of ASTM E 488 should be described in section 4.4 to allow for double-shear test specimen tested vertically. Measurement of vertical deflection should be defined better; if one Linear Variable Displacement Transducer (LVDT) is enough or more than one LVDT's are required and their location should be specified. Section 4.4.1.2 should be elaborated in installation of the connector as connector does not have any mechanism to set the connector to the correct concrete embedment depth. Also, I think reliability tests should be conducted since the depth of embedment will affect the shear strength and shear modulus values due to uncertainty in installation methods.
26. In section 4.4.1.3, line 260 allows connector to be in single row or multiple rows. However, the equation on line 168 is based on only two rows of connectors. In line 261 and 262, the connector length is required to be same length of the concrete element, which does not allow the shear test for semi-continuous connector if the connectors are separated by six inches.
27. In line270, modify "....can be interpolated for results of other thickness;" to read "....can be interpolated for results of other thickness provided all other connector design alternatives are same;"
28. In section 4.4.2, the acceptable coefficient of variation (COV) should be added.
29. In line 287, words "connector grids" are used in that order while in other sections words "grid connector" are used. Are both pairs of words meaning the same? If so, line 287 should be changed. If the meaning in line 287 is in fact different and means the 8-ft wide roll or sheet sent

to the panel manufacturing facility, shouldn't the cutting of the connector from the roll or sheet be under the quality program per AC10?

30. In section 6, a statement requiring special inspection should be added. A statement regarding the connector not being suitable for fatigue and shock loading should be added. A statement regarding the use of the connector in uncracked concrete should be added.
31. In line 307, Section 4.4.2 should be changed to Section 4.4 since the entire section is pertinent in qualification testing.
32. In section 1.4.3.3, w_{max} is defined but I could not find the reference and its effect anywhere else in the criteria. What is the maximum connector spacing, 2-ft, 4-ft, or other?
33. Is there a limit on the thickness of insulation?

Again, it is unclear from AC422 how to use the evaluated shear flow and shear modulus properties of the grid connector in the design of the sandwich wall panels. It is also unclear if the design procedure using the continuous grid connector is the same as a semi-continuous grid connector. I think more information should be given in AC422 to aid the panel designer.

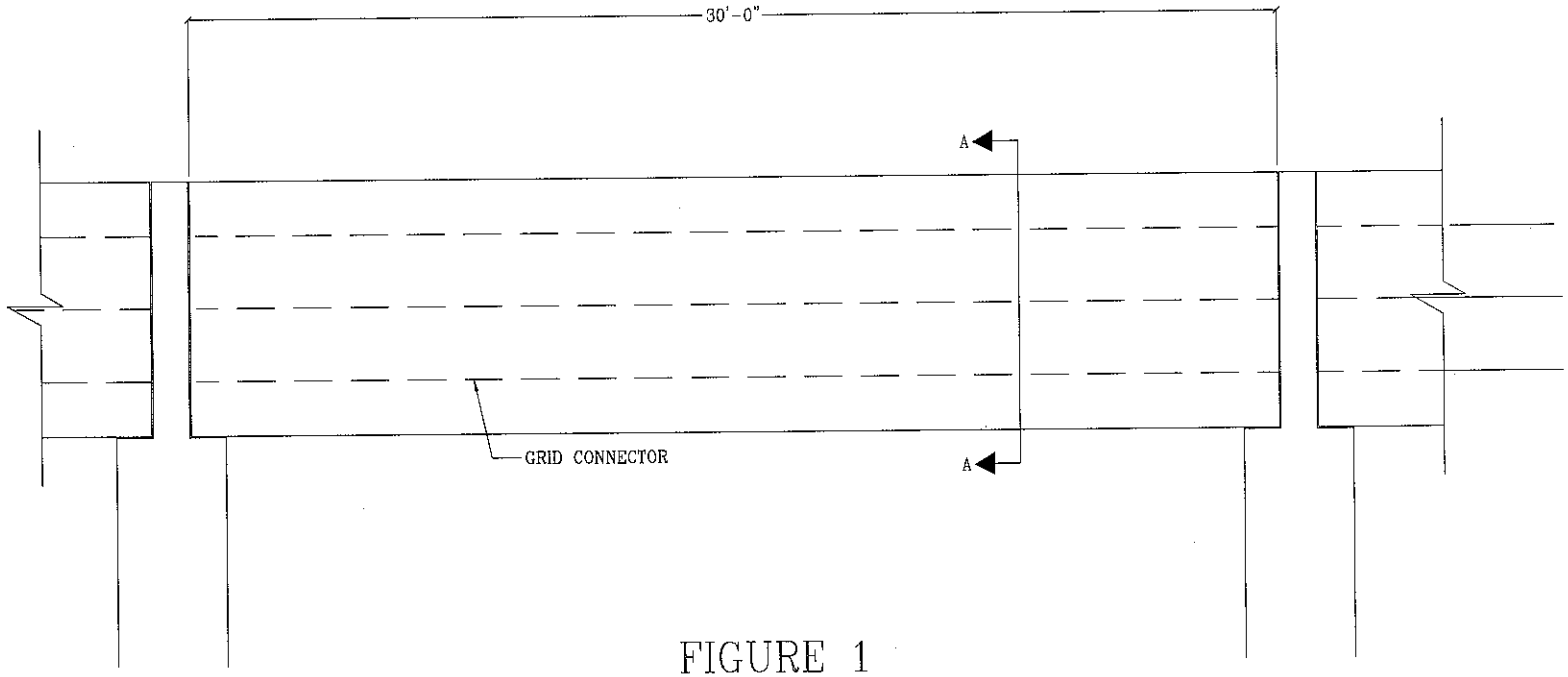
I have attached a table that compares the required tests in AC320 and AC422.

If you have any questions and would like to discuss any of the items, please feel free to contact me at (800) 232-1748 or e-mail at vseshappa@thermomass.com.

Sincerely,

Venkatesh Seshappa

Venkatesh Seshappa, P.E. & S.E.
Director of Engineering


30'-0"
A
A
GRID CONNECTOR

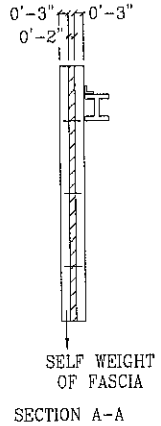

0'-3"
0'-3"
0'-2"
SELF WEIGHT
OF FASCIA
SECTION A-A

FIGURE 1

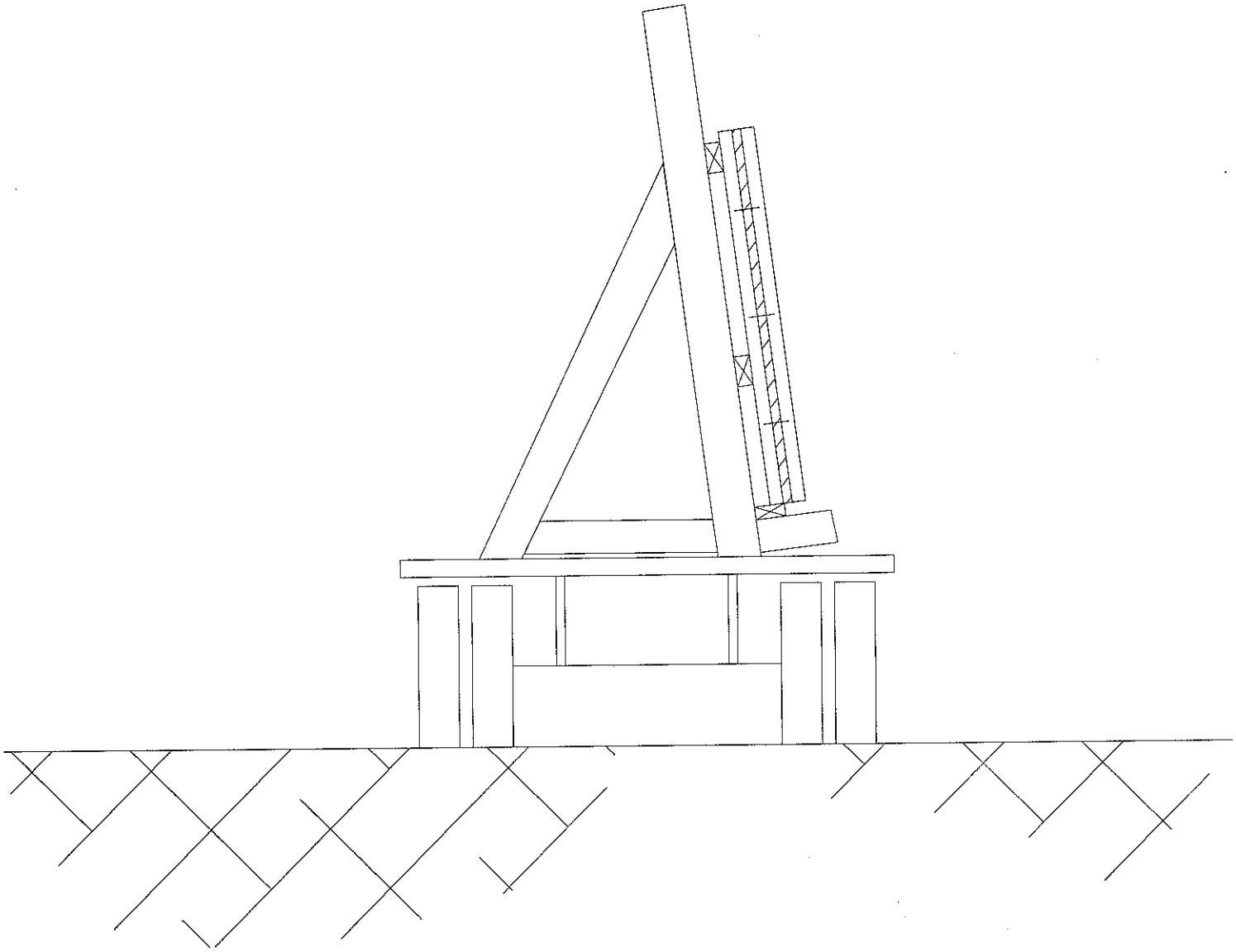


FIGURE 2

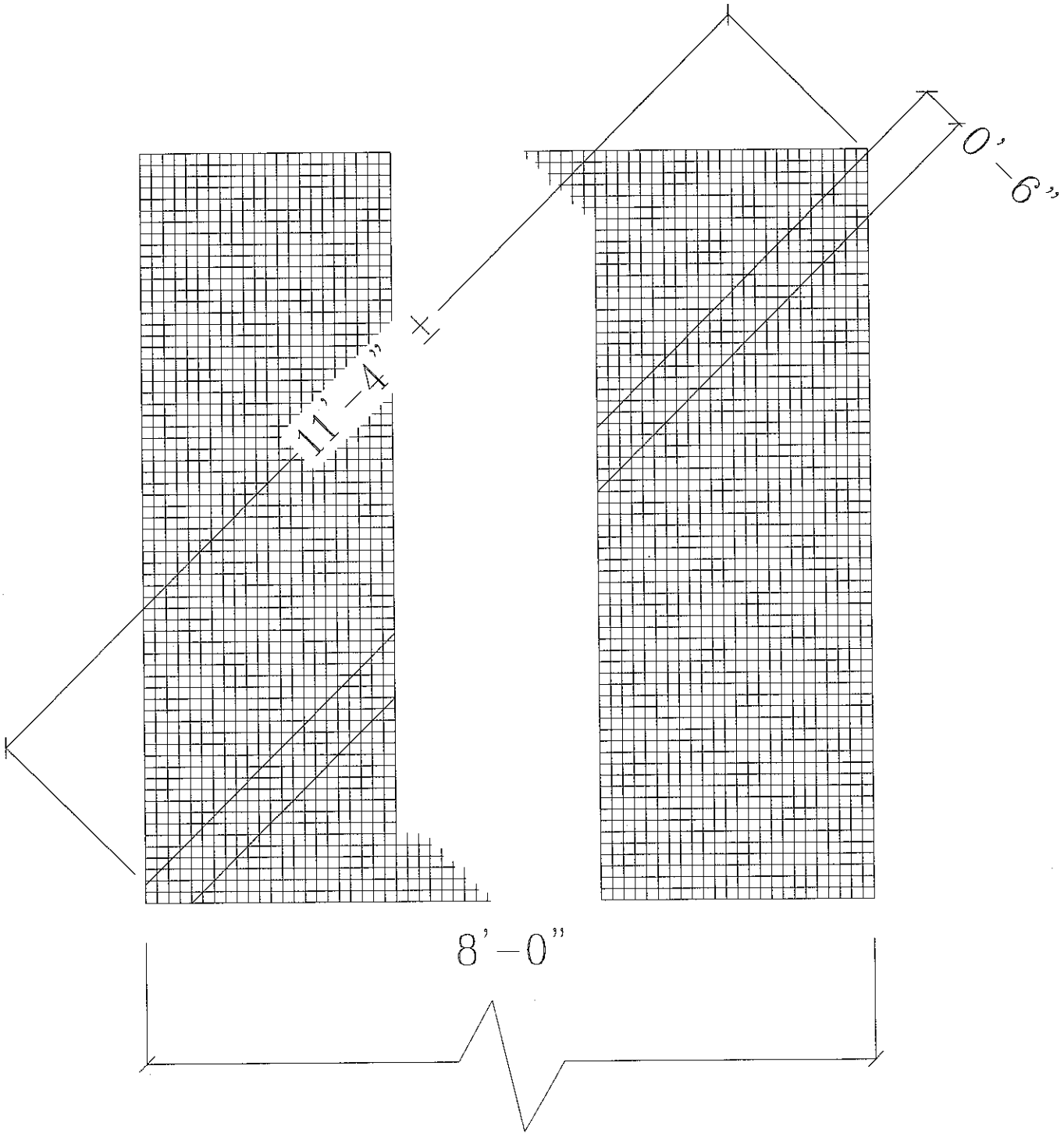
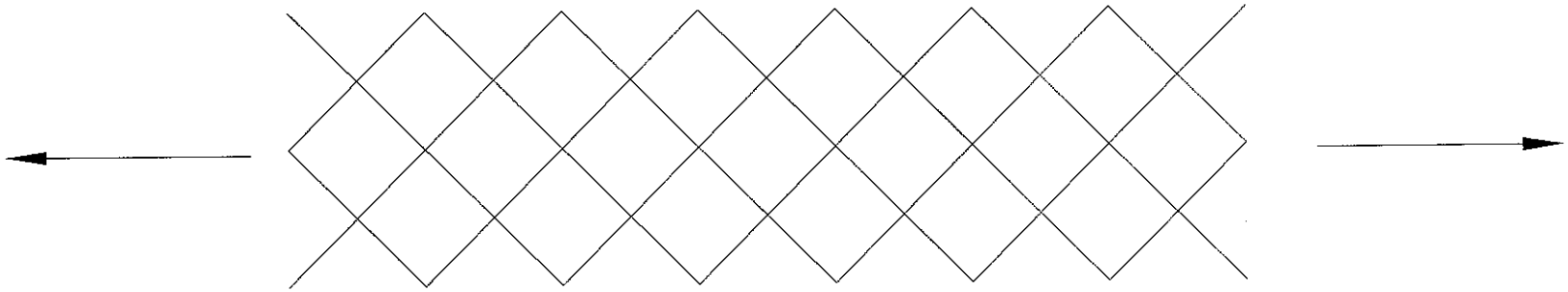


FIGURE 3



CORRECT TENSION TEST

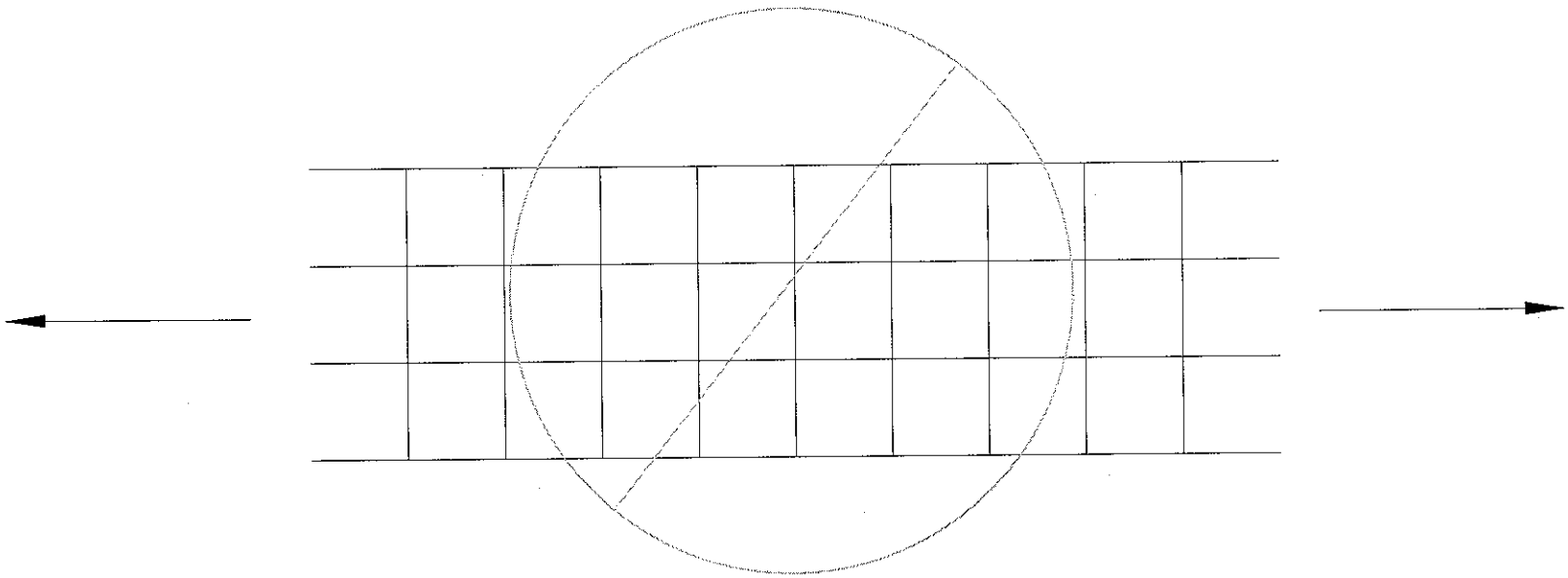


FIGURE 4

Comparison of AC320 & AC422 tests			
Test Type	**AC320**	**AC422**	**Reason for Evaluation**
Tension of connector	Yes	Yes	Connectors are subjected to tension loads due to wind and seismic forces
Flexural	Yes	No	
Aging - Moisture (1000 hrs.)	Yes	Yes	Environment and Aging
Aging - Moisture (3000 hrs.)	Yes	Yes	Environment and Aging
Aging - Wet Conc (1000 hrs.)	Yes	Yes	Environment and Aging
Aging - Wet Conc (3000 hrs.)	Yes	Yes	Environment and Aging
Static Tension in Concrerte	Yes	No	Pullout of connector from connector due to wind loading and bending
Static Shear - Strong Axis	Yes	Yes	Shear strength in strong axis, fascia deflection or shear flow for bending in longer direction
Static Shear - Weak Axis	Yes	No	Weak axis bending - spandrel beam
Creep Test at Elevated Temperature	Yes	No	For Long Term loading
Cyclic Tension Test (optional)	Yes	No	Seismic
Cyclic Shear Test (optional)	Yes	No	Temperature expansion/contraction