Brian Gerber, S.E.
Principal Structural Engineer
ICC Evaluation Service, Inc.
Los Angeles Business/Regional Office
5360 Workman Mill Road
Whittier, CA 90601

Subject: ICC-ES AC391 Acceptance Criteria for Continuous Rod Tie-down Assemblies

Dear Mr. Gerber,

Below are some comments on AC391.

Feel free to call or e-mail any questions/comments you may have.

Sincerely,

Marty Downs, P.E.
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Section 1.2.1.1
A floor system is not a rigid boundary and treating it as such will in most instances underestimate the drift of a light framed wood structure. Drift performance of the entire system tested needs to be considered in calculations. Irregardless of how tight the system is at the onset of testing, if the differential of stiffness between the wall studs and the bottom plate and/or the double top-plate the studs are bearing on is included in the calculations it will significantly increase the overall calculated system drift. The inclusion of a linear springs at the floor system boundary using the E-perp of the wall bottom/top plate for stiffness should be included in the total system's drift/overturning calculations until testing warrants the exclusion of this drift component from calculations.

Section 2.3
Actual test assemblies defined within AC391 should have more detail. The wall width and heights should be explicitly stated, sheathing thicknesses, nailing spacing for both edge and field and nail material properties should be detailed, additional fastener types, size and material properties should be defined, lumber species and grade should be defined. Geometry of the assembly should be defined. An example for this reasoning for these inclusions is that different OSB/plywood manufacturers produce different quality of product. If testing is performed using a high grade proprietary sheathing material instead of commodity grade material this will skew system testing results. An example of

boundary conditions of the assembly that will impact results would be window opening within the specimen. The corners of the windows will dissipate an unquantifiable amount of the energy input into the system. The point is that since a system is being tested the whole system should be well defined within AC391 so that the comparative performance can be evaluated for each manufacturer and there is assurance that each manufacturer can achieve a minimum performance from a standard specimen.

Section 4.2

Reporting the results of the best of three tests from a series of tests skews the results and results based on only three tests is statistically insignificant. To understand the performance of the proposed system a minimum of 78 separate tests should be performed using one well defined system to ensure what is reported is statistically sound. From this data smaller numbers of tests on the high/low end of the design spectrum can be performed to develop an envelope for the full suite of offerings from the manufacturer. Without that there is no way to understand performance of a manufacturer's proposed system.

Section 4.2

Based on the statics of the deformed shape of the system it appears the impact of having multiple rod systems on a single wall line will be that that only the rod systems on the exterior of the test specimen will be engaged. Therefore this section should require one rod system per wall line in the testing. It is also unclear how the loads applied to multiple rod systems in a single wall line could be uncoupled to determine the percentage of load applied to each individual rod system.

September 3, 2009

Mr. Brian Gerber, SE
Principal Structural Engineer
ICC Evaluation Service
5360 Workman Mill Road
Whittier, CA 90601

SUBJECT: AC391 Comments to version AC391-0609-R3

Dear. Mr. Gerber:

This letter addresses the numbered comments and items from your letter dated August 7, 2009. Throughout this response all changes reference the ICC-ES published AC391 dated June 2009 with an effective date of July 1, 2009 and not the as proposed submittals of Simpson Strongtie or Commins Manufacturing unless specifically noted. It appears that the AC391 version used in the Simpson letter is a prior version.

Item 1: Sections 1.1, 1.2.1: *The proposal would limit the use of the tie-down assemblies to vertical wind (uplift) restraint only. The reason given by Simpson was that "continuous rod tie-down systems to resist overturning force are completely different from rod tie-down systems for wind uplift ..." It is unclear how these systems are different and why systems used to resist overturning forces should not be included in AC391.*

Response: Section 1.1, 1.2.1: The task group believes there is no valid reason why this AC should be limited to wind only. This AC provides an applicant to publish capacities of components of a threaded rod assembly for the design professional to use for either wind or seismic. The petitioner's own product line includes hold-downs used for <u>either</u> wind or seismic use. The resisting capacities of the threaded rod assembly are the same whether the load source is resulting from wind or seismic.

It is also the opinion of the group that the existing wording in Section 1.2.1 is sufficient with the following change:

"… Lateral or uplift load-resisting system considerations, including shear wall geometry, shear resisting element size, shear resisting element material, fastening, <u>flexural member design,</u> and compression framing shall be considered and designed separately and are outside the scope of this criteria…"

Item 2: Section 1.2.1: *The statement requiring the continuous tie-down assemblies to be considered as independent was stricken. In addition, a statement was added indicating the uplift resisting performance needs to consider other aspects outside the continuous tie-down assemblies such as wood shrinkage, compression framing design, and flexural member design. The testing proposed in Section 4.2.2 would be used to* *confirm performance of a wall with the continuous tie-down assemblies. This revision would require a relatively prescriptive application in the evaluation report. Some earlier comments on AC391 indicated adequate information existed to permit design for a specific project. Therefore a question arises to whether a prescriptive installation should be included, which may serve the needs where structural design is not always done, such as dwelling construction, whether a design by a professional should be maintained or whether both approaches can be utilized.*

Response: The verbiage change suggested above addresses the concern of the petitioner regarding the difference between uplift and overturning design. Designs of buildings are unique. The change we suggested would not give an advantage to one manufacturer over another, nor would the change hinder any future manufacturer. With regard to a prescriptive method of design, many examples of prescriptive methodology exist and none are universally accepted. It is the opinion of the group that acceptance of prescriptive methods should be left to local building officials to determine whether or not an evaluation report meets the intent of the prescriptive method accepted in their jurisdiction.

Item 3: Section 1.2.3.4: *This section is proposed for deletion. It is not clear whether the deletion is intended to allow cable or rope as a component or whether the deletion is to remove a supposed redundancy with the scope and definition, which limit the assemblies to threaded rod.*

Response: We believe this paragraph should remain and maybe add "is outside the scope of this criteria." as a reminder that this paragraph is under Section 1.2.3. The intent of this AC391 is for threaded rod only as the tension member.

Item 4: Section 1.4.2: *It will be informative to understand the reasons why the steel rod length has been taken as greater than one-half the story height.*

Response: We suggest the following change in Section 1.4.2:

"A continuous rod tie-down assembly consists of the following components: (1) steel rods; (2) metal intermediate connectors or coupling devices used to attach the continuous rod tie-down components, such as hold-downs evaluated in an ICC-ES evaluation report in accordance with AC155, or shrinkage compensating devices evaluated in an ICC-ES evaluation report in accordance with AC316, if applicable; and 3) steel bearing plates or plate washers used ~~to enhance the performance of~~ in the assembly.

Item 5: Section 3.1: *There appears to a conflict in the proposed revision. The first sentence indicates testing is permitted, provided the test-based values do not exceed calculated values. The second sentence allows for testing where assemblage values cannot be readily confirmed by calculation. If calculations cannot be easily utilized as stated in the second sentence, this premise conflicts with the first sentence, which expects calculations to be done in order set the limits on capacity.*

Response: The intent of this section is to provide a method of testing that is used in lieu of or to supplement the calculation of the design strength of a component or assembly. It also provides a means to include testing of proprietary components of a threaded rod assembly that cannot be easily justified by calculation means. Section 3.1 should remain unchanged.

Item 6: Section 3.2.1.1: *It appears that any steel component may be subject to strength adjusted as proposed. However, the definitions for* $F_{u(spec)}$ *and* $F_{u(test)}$ *limit applicability to steel bolts.*

Response: This change is not necessary since the tested values cannot exceed the calculated values and the existing section provides a proportional reduction for higher material strengths over standard or the minimums required by QC documentation.

Item 7: Section 3.3.1: *Section 3.3.1 was intended to provide a global requirement for factors of safety, except for threaded rod couplers, which are addressed in Section 3.3.2. The proposed change revises this section to apply to the threaded rods only and other components along with assembly performance have been omitted from consideration.*

Response: We propose the following change:

"Continuous Rod Tie-down Assemblies and Components: Except as set forth in Section 3.3.2, ~~3.3.3~~ and 3.4, the allowable load shall be determined as follows:"

The suggested change to the rod Factor of Safety is not necessary for tested components.

Item 8: Section 3.4.1: *The criteria needs to be reviewed to fully allow for LRFD design, including determination of factors of safety for tested assemblies and components.*

Response: The task group will further examine the applicability of LRFD design provisions for this AC. Our intent will be to examine the applicability of AF&PA/ASCE 16-95 – Standard for Load and Resistance Factor Design for Engineered Wood Construction in this AC. At first glance, it appears that an applicant could furnish strength level design values for components easily, but the limiting component will still be the connection to wood which is a bearing plate. We will be preparing a more comprehensive response.

Item 9: Section 3.4.6: *This revision proposes that a double plate may act as a structural composite in resisting bending. This composite would be determined by testing. Connections between the two plates should laminate the two members together and be connected across splices for added flexural tension resistance.*

Response: The verbiage change from Item 1 addresses the proposed change from Simpson Strong Tie. Since overturning resistance is covered in this acceptance criteria this section is necessary.

Item 10: Section 4.1.1: *As with Section 3.3.1, this revision implies that testing of the rod only is permitted and not other components. This change conflicts with Section 3.1 where testing is allowed for a component that does not comply with the codes or available acceptance criteria.*

Response: Refer to our response for Item 5. Section 4.1.1 should remain unchanged.

Item 11: Section 6.2.2.2: *It is unclear on the reasons why shrinkage compensating devices are required where continuous tie-down assemblies exceed two stories in height.*

Response: Shrinkage compensation devices are not code required and provisions for including them optionally in individual reports have been provided in the acceptance criteria as published. This proposed revision is interesting since the petitioner's superior has provided prior testimony at ICC hearings that shrinkage compensating fasteners aren't required. Section 6.2.2.2 should remain unchanged.

Additional Item: *The Commins proposal requests that threaded rod couplers be allowed to comply with IFI-128, 1986 edition as an alternative to testing as currently required in Section 4.5 of AC391. This proposal is unclear on the couplers' structural performance relative to the connected threaded rod: Should proof tests in a manner similar to nuts AC391-0809-R1 3 be used or should calculations based on the couplers' net area and steel tensile or yield strength be permitted?*

Response: With regards to the Commins proposal: The proposed IFI-128 standard is a <u>dimensional standard</u> only and does not specify material requirements. It only provides dimensions for straight thru couplings with a single sight hole and does not address load rating or reducer couplings.

Proof load tests of couplings (we believe Commins was referring to provisions of ASTM F606) would only reveal the capacity of the threads themselves for one side of the coupler and does not address the required cross sectional area of the coupler to meet the tension requirements of Section 4.5.

We believe the intent of AC391 is for the applicant to provide testing of all their listed sizes in accordance to Section 4.5 and not allow a calculated method.

Thank you for the opportunity to submit comments. Please call or email if you have any questions.

Edward Chin, PE
Vice President
Earthbound Corporation

Ward Gould
President
Go-Bolt, Inc

Joe Hale
Senior Engineer
Hurri-Bolt, Inc.

Bill Wade
Director of Sales and Marketing
TIE MAX

SIMPSON Strong-Tie®

September 2, 2009

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Subject: ICC-ES AC391 Acceptance Criteria for Continuous Rod Tie-down Assemblies

Dear Mr. Gerber,

Attached please find our responses to your comments dated 8/7/09 for ICC-ES AC391 entitled "Acceptance Criteria for Continuous Rod Tie-down Assemblies." After review of our attached rationale for our proposed revisions to AC391, we request that this Acceptance Criteria be placed on the next ICC-ES Evaluation Committee agenda (October 2009), as we requested in June, in order to review and approve the recommended revisions.

Please email me at lmcgurty@strongtie.com or call me at 925-560-9000 with any questions or comments you may have.

Sincerely,
Simpson Strong-Tie Co., Inc.

Lisa McGurty, PE dw/SH,BW
Senior Engineering Project Manager

Attachment: ICC-ES AC391 Explanation for Requested Revisions

Copies: Ricardo Arevalo, Simpson Strong-Tie
Jeff Ellis, Simpson Strong-Tie

ICC-ES AC391 Rationale for Requested Revisions

Comment #1 Sections 1.1, 1.2.1: The following discussion provides rationale to why continuous rod tie-down systems which resist overturning forces are different from rod tie-down systems that resist wind uplift, and, thus, why overturning systems should be removed from this AC. Please note that others, including several structural engineer designers, also stated in writing and verbally at the June 2009 ICC-ES Evaluation Committee meeting, that these two systems should not be combined, and that assemblies resisting overturning be eliminated as they can simply be calculated in accordance with the code.

Overturning restraint systems and uplift restraint systems have completely different load paths, applied forces, and functions. One use of continuous rod tie-down systems is as overturning restraint in light-frame shear walls. The load path in a continuous rod tie-down system used to resist shear wall overturning is as follows: Due to the shear wall sheathing fasteners, the end posts lift below the framed floor level, concentrically transferring forces to the bearing plate and nut and then into the rod. Overturning restraint systems receive load at each diaphragm level. The result is the bearing plates only resists the incremental overturning forces applied at each level, while the rods and couplers resist the cumulative forces, which increase at each point of restraint. ASD demand forces at the bottom level can be as much as 50 to 60 kips.

Another use of continuous rod tie-down systems is to resist uplift forces. The load path in a continuous rod tie-down system used as wind uplift restraint is as follows: The roof trusses eccentrically transfer the forces into one side of the double top plates, forcing them to bend and twist (rotate). The top plate then transfers the forces to the bearing plates and nuts, and the forces are then transferred into the rods, which are spaced at some interval along the length of the top plate. As a result, these systems are loaded at the upper most top plate only, and the load through the rod is the same the entire way down the structure. ASD demand forces through the rod are typically 3 to 5 kips.

ICC-ES AC391 Section 3.4.4 entitled "ASD Allowable Load and Deflection" states that the allowable loads for the assemblies are based on the lowest determined allowable load of any component or connection of components comprising the intended assembly. This cannot possibly apply to overturning restraints in shear walls because the forces are added at each floor at the bearing plate and nut, as explained above. Therefore, the component with the lowest value for that level (most likely the bearing plate) cannot limit the rod capacities, as each component has to be looked at individually. See Figures 1 and 2 for an illustration of the differences in load paths and demand loads.

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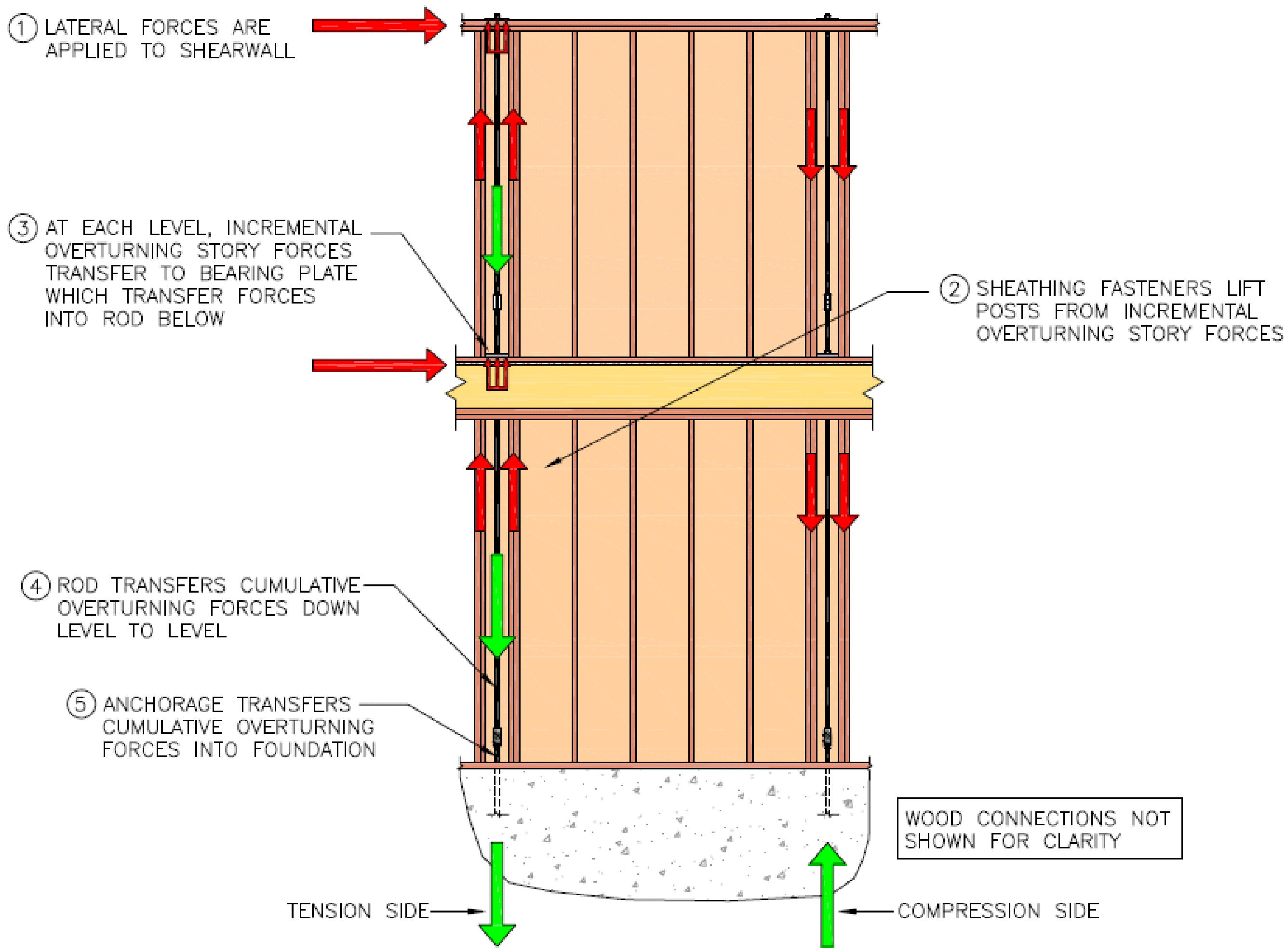

Figure 1

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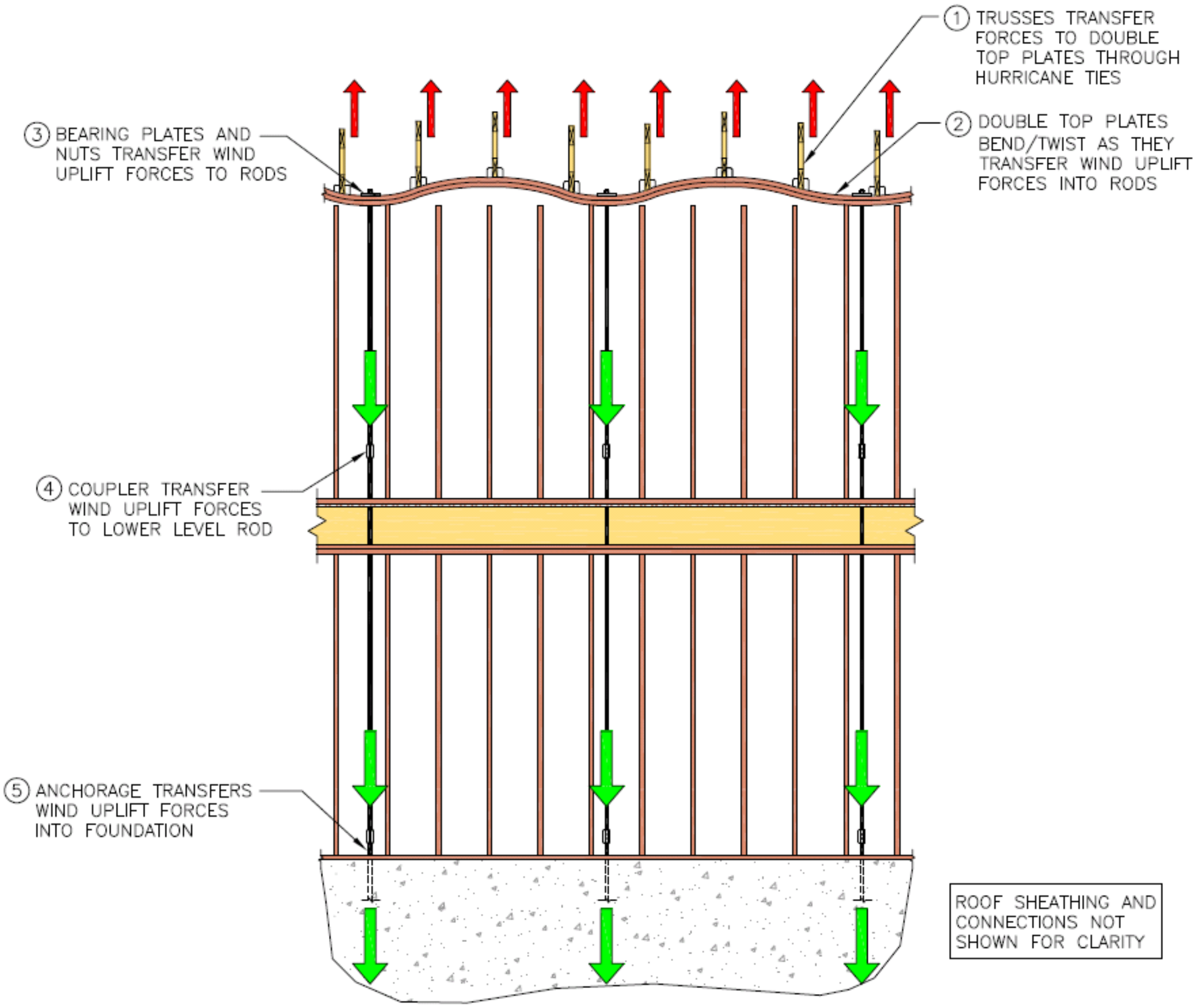

Figure 2

Comment #2 Section 1.2.1: The proposed additions to AC391 Section 4.2.2 were meant to include testing in addition to calculations for the continuous rod system used to resist wind uplift flexural member (top plate) design. This addition was proposed for non-prescriptive applications, similar to other structural product AC's requiring testing of the product connected to the actual supporting and supported members representative of field installed conditions. Examples of Acceptance Criteria requiring products tested using members representative of field conditions are AC13 (joist hangers for wood construction) and AC155 (hold-downs for wood construction).

AC391 should require that the load capacity of continuous rod systems be based on the lower of the following: (1) the calculated strength and calculated elongation (using the net tensile area) of the steel tension rod, (2) the calculated strength of the bearing plate on wood, (3) the calculated or tested strength top plate bending, (4) the calculated or tested wood top plate deflection, and (5) the calculated or tested strength of the rod coupler. The following comments are further

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proposed modifications for continuous tiedown systems which resist wind uplift. They modify the AC to clearly designate that the strength and elongation of the rod and bearing plate shall be calculated, and that the system can be calculated or tested (in an assembly test). However, some elements may be difficult to calculate, which are further explained below. Please reference Comment #5 for more information.

Comment #3 Section 1.2.3.4: This section, which excludes wire rope and cables, should not be removed from AC391. We agree that there are vast differences in cables, such as prestressing, relaxation, and extra deflection due to the cable stretch. These systems should have their own AC written specifically to address these issues.

Comment #4 Section 1.4.2: We are in agreement to remove the clause regarding steel rods with a minimum of ½ the story height. Please refer to comment #7 for modifications to Section 1.4.2.

Comment #5 Section 3.1: Since the code gives specific direction on how to calculate capacities and deflection of bearing plates and rods, the plate and rod assembly tested on a steel jig should never be tested. This would create a possibility that load values may determined in a manner that violates the code (e.g.; testing components and determining loads greater than one could calculate in accordance with the code).

Conversely, there is not specific guidance on how to determine the adequacy of the double top plates considering eccentricities, effects of top plate splices, length of top plate span, application of a continuous load or point loads, etc. Using engineering judgement, the wood bending and deflection may be calculated with some difficulty; however, top plate rotation would be next to impossible to simply calculate. Therefore, tests of these assemblies and comparison to performance of assemblies that have performed well in the decades past are necessary. Note that although the rods will be needed to perform a full scale test, their capacities will always be limited by calculation. See Figure 3 below for a picture to show why top plate bending consideration is critical. We propose the following modifications to Sections 3.1 and 3.1.1.

> **3.1 General:** Allowable loads for threaded rods and bearing plates shall be determined ~~by testing in accordance with Sections 3.1 through 3.3 of this criteria of this criteria or~~ by calculations in accordance with Section 3.4 of this criteria. Testing in accordance with Sections 3.1 through 3.3 of this criteria may be utilized where the assembly contains a component that does not comply with a referenced standard or acceptance criteria (such as double top plates); or where the system assemblage performance cannot be readily confirmed by calculation~~; or when testing proves consistent performance exceeding calculated predictions and components is produced under a continuous quality control program where characteristics are correlated with test specimens~~. ~~Testing, when used,~~ Calculations shall include ~~tests of~~ various lengths of ~~assemblies~~ threaded rods to confirm length effects on deflection. ~~When allowable loads are determined by testing, testing shall be in accordance with Sections 3.1 through 3.3 of this criteria.~~
>
> **3.1.1 Tension Load Testing:** ~~Continuous rod tiedown~~The system ~~components~~ shall be tested such that a tension load is applied in reference to the intended application ~~of the components~~

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when attached to a test apparatus as described in Sections 4.1 through 4.3 of this criteria. ~~The ASD allowable steel tension load capacity shall be calculated from tested maximum load in accordance with AISC 360 or in accordance with either AC155 or AC316, as applicable.~~ In addition, load deflection characteristics shall be reported. The allowable vertical load for a normal duration of loading of the system shall be the lowest value determined from tests using the criteria given in Sections 3.3.1.1, 3.3.1.2, or 3.3.1.3.

Figure 3

Comment #6 Section 3.2.1.1: As stated above, rod and bearing plate capacities are calculated by code, so the $F_{u(spec)}$ and $F_{u(test)}$ will not apply. However, if the manufacturer can provide quality documentation showing that their steel strength is greater than the minimum ASTM standards, then the calculations should be calculated based on that higher standard. The proposed sections below also include requirements for field identification. We propose the following modifications to Sections and 3.2.1 and 3.2.1.1

3.2.1 Steel: The steel properties of the tested continuous rod tie-down components, including yield point, tensile strength, elongation, and uncoated base-metal steel thickness, shall be determined by ~~testing in accordance with the corresponding referenced standard. As an alternative,~~ mill certificates ~~shall be provided~~ for the specific heat or lot of material subjected to the ~~load~~ tests as described in this acceptance criteria.

3.2.1.1 Standard Steel Components Used in Typical Assemblies: If mill certificates show that ~~tested~~ yield and tensile strengths ~~or dimensions~~ of the steel components exceed minimum specified values as established in accordance with Section 2.1 of this criteria, the allowable loads determined in accordance with Section 3.3 shall be proportionally reduced. If the product under consideration uses materials with yield and tensile strengths always greater than the minimum specified by the referenced standard, and these higher strengths are

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confirmed by the quality documentation, then the calculations based on the higher strength can be used. The higher strength, non-standard products shall be identified with etching and color-coding to clearly identify them. In addition, periodic special inspection is required to ensure proper installation. Verification of the higher strength material certifications in the quality control documentation by an accredited inspection agency shall be required in the quality control documentation as applicable.

Comment #7 Section 3.3.1: The factor of safety was meant to be on the entire system, not just the rods and bearing plates, as the rods and bearing plates are to be calculated in accordance with the code. The assembly allowable design value should be the lower of the ultimate load divided by a factor of safety of 2 and the load at the deflection limit. Note that Section 1.4.2 states that continuous rod tie-down assemblies shall include all components that are needed to transfer tension loads from the point of origin in a structure into a supporting element such as a foundation. As such, the double top plates are transferring loads from the trusses to the rods, and should be considered in the "assembly" definition of this AC. We request the following revisions be made to sections 1.4.2, 3.3.1, 3.1.2, and an additional Section 3.3.1.3, with the following sections renumbered accordingly. In addition, we request striking our previous revision recommendation in our letter dated June 22, 2008 to add a Section 4.3.2.3.

1.4.2 Continuous Rod Tie-down Assembly Components: A continuous rod tie-down assembly consists of the following components: (1) steel rods (2) ~~metal intermediate connectors or~~ coupling devices used to attach the continuous rod tie-down components, ~~such as hold-downs complying with AC155 or shrinkage compensating devices complying with AC316, if applicable; and~~ (3) steel bearing plates or hold-downs complying with AC155 ~~or washers used to enhance the performance of the assembly.~~; (4) any framing members which transfer loads to the rods; and (5) shrinkage compensating devices complying with AC316 when determined necessary by the Designer or when the structure is greater than two stories in height. System anchorage to supporting element (i.e. foundation) is outside the scope of this criteria, but must follow applicable code and standards.

3.3.1.1 Where the assembly test sample size is three to five, the allowable load is the lowest peak value from a single specimen divided by a factor of safety of ~~3~~ 2.

3.3.1.2 Where the assembly test sample size is six or more, the allowable load is the mean peak value from all specimens divided by a factor of safety of ~~3~~ 2.

3.3.1.3 Deflection Limitations: The maximum allowable load at deflection of the tested wood top plates shall be limited to L/180, where L = top plate span equal to the distance between rod restraints. See Section 4.3.2.2.

Comment #8 Section 3.4.1: Simpson welcomes the opportunity to work with ICC-ES to develop LRFD capacity and deflection limits for AC391.

Comment #9 Section 3.4.6: We agree that the top plate splices could be connected together to transfer load. Obviously, different top plate splice connection details would yield different load

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resistances. However, without testing of the entire assembly, calculations could only support a single wood top plate being relied on in bending to transfer loads to the tension rods. Testing of top plate splice connections could allow the use of two top plates in bending – increasing capacity, but ultimately limited by the calculated capacity of a wood double top plate. The additional requirement in Section 3.4.6 ensures that this is done properly. Additonally, testing has shown that the double top plate splice is critical. Please see figure 4 below.

> **3.4.6 Top Plate Calculations**: For wind uplift resistance, ASD load values based on the wood top plate resisting bending between the tension rods shall be determined in accordance with the AF&PA NDS considering only a single member of the wood top plate, unless it can be shown by testing that double top plates are sufficiently fastened together at wood plate splices to provide increased bending capacity. Top plate splice details shall be provided in the code report. The maximum calculated deflection of the single wood top plate shall be limited to L/180, where L = top plate span equal to the distance between rod restraints.

Figure 4

Comment #10 Section 4.4.1: Testing of the entire system (assembly) should be completed in lieu of the rod and plate only. As such, please see section 4.1.1 below modified and replace Figure 1 in the AC with the Figure 5 below.

> **4.1.1 Rod Tension Testing Machine:** ~~A testing machine that is capable of operation at a constant rate of motion of the movable crosshead or a constant rate of loading, and a force measuring device that is calibrated in accordance with ASTM E 4, shall be used. A typical~~

~~apparatus is illustrated in Figure 1~~. A testing machine that is capable of attaching to a wood wall assembly at 16"to 24"o.c. with independent uplift load actuators capable of operation at a constant rate of motion of the movable crosshead or a constant rate of loading, and force measuring devices that are calibrated in accordance with ASTM E 4, shall be used. A typical set up for testing the continuous rod tie-down system on a wood wall assembly is shown in Figure 1.

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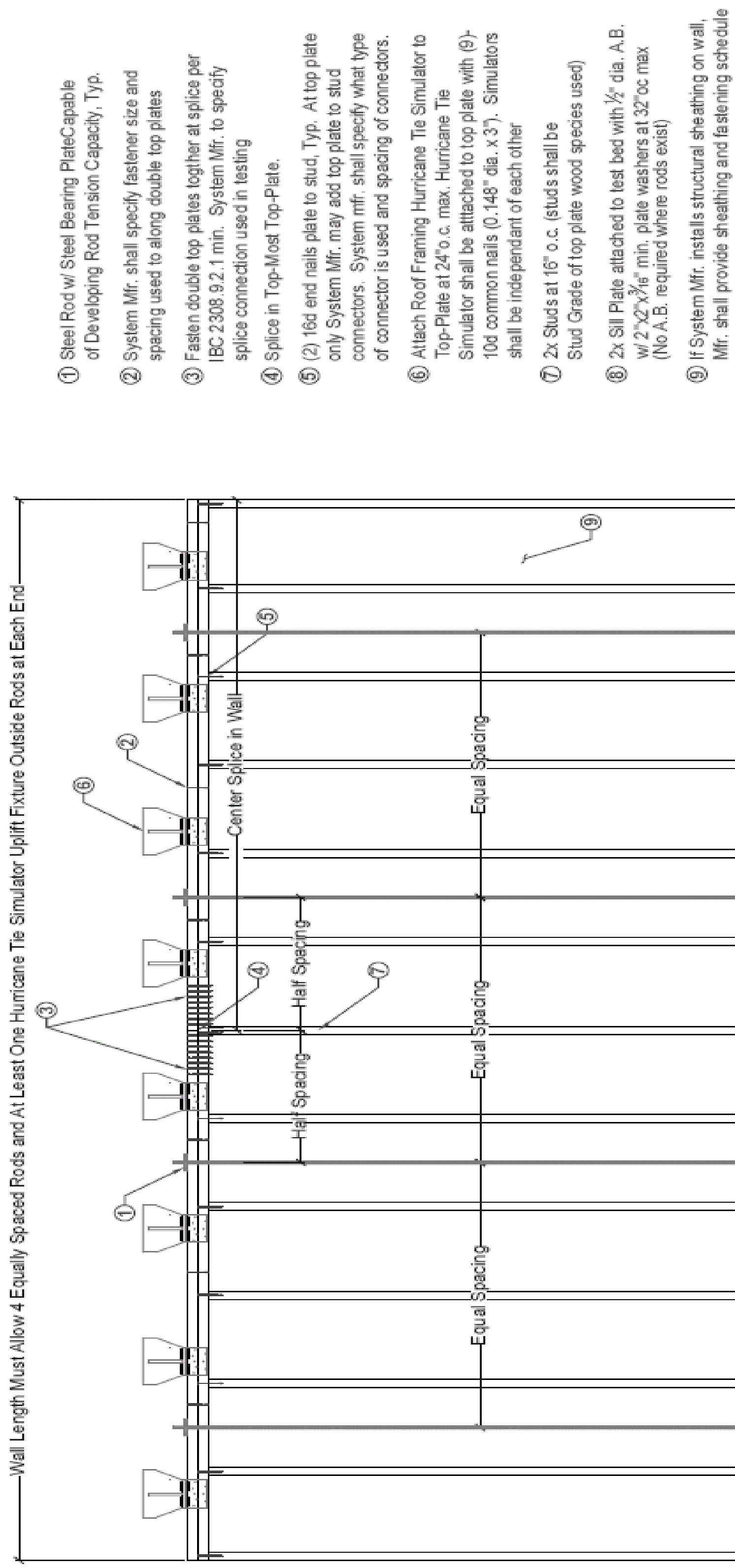

Figure 5

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Comment #11 Section 6.2.2.2: Past installation inspections have shown that the shrinkage accumulates at the top level as the building shrinks. As the stories increase in the building, total shrinkage increases, which will accumulate at the top of the uplift system, creating a gap between the nut and bearing plate at the top floor. See Figure 6 below.

Figure 6

Response to Mr. Commins proposal regarding coupling nuts: We are supportive of this section relying on ASTM A563 or meet minimum requirements for the rod ultimate and tensile. However, a correction is that the rod tensile and yield capacities are based on net area in lieu of gross area. We propose that Section 3.4.3 be rewritten as follows:

> **3.4.3 Nuts and Couplers**: Nuts and thread engagement length of couplers shall comply with ASTM A 563. High- strength-grade nuts and couplers shall be used with corresponding high-strength-grade threaded rod. When calculating the minimum dimensions of a coupler, the cross-sectional area and thread engagement length shall be sufficient such that the coupler strength exceeds the greater of 100 percent of the specified tensile strength, fu of the threaded rod or 125 percent of the specified yield strength, fy, of the threaded rod, based on threaded rod ~~gross~~ net cross-sectional area (A~~g~~n).

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