Q: **How do the inspectors ensure the specified inclination angle of the screws? How do the inspectors ensure the overlap dimension, such as the 4D mentioned?**

A: The ASSY fasteners (ICC-ES and CCMC certified) have the brand (ASSY) and the screw length punched onto the screw head–the only exception is the ASSY VG Cyl as the head is too small. An inspector can verify that the proper fastener brand and length was installed, however, just as rebar cannot be inspected once the concrete is poured, once the screws are installed the overlap length and screw angle may not be verified. Another solution would be to inspect the fasteners as they are being installed. For installers, jigs are recommended to ensure consistent angle of inclination between fasteners and a short pilot hole can help assure the correct install angle. For steel to wood connections, jigs also ensure the screws sit at the precise location within the holes/slots fabricated to accepts the screws/washers.

Q: **Can I apply short term loading factors if I am close to reaching the tensile capacity of an inclined fastener?**

A: Load duration factors apply to wood properties, and not steel properties. Therefore, *adjusted* withdrawal resistance should be compared to *allowable* tensile strength when designing according to NDS 2018. Likewise, the *factored* withdrawal resistance should be compared to the *factored* tensile strength when designing according to CSA O86.

Q: **Do we need to consider group action factors for inclined fasteners?**

A: For inclined screws, it is sometimes suggested to use the group action factor of $n^{0.9}$, which is an empirical equation for axially loaded fasteners taken from Eurocode 5. This is generally regarded as overly conservative for inclined screw joints when large numbers of fasteners are acting together. For lateral connection using inclined axially loaded screws, the number of effective fastener should be: $n_{ef} = \max\{n^{0.9} : 0.9 \cdot n\}$. The $0.9 \cdot n$ factor comes from investigations made by Krenn & Schickhofer (2009) with inclined screws with steel side plates where the screws fail in withdrawal (this factor is now included in many European design documents, and has been validated). Others have proposed that $n_{ef} = n$ for timber to timber joints (Kevarinmäki, 2002; Blass, Bejtka & Uibel, 2006; Tomasi, Crosatti & Piazza, 2010), but applying $0.9 \cdot n$ factor covers all applications. It should be noted that reduced n_{ef} factors may sometimes be used for calculating serviceability limit states. For high capacity steel to wood connections where the wood screw head is bearing against a steel plate we typically suggest to follow the install torque guidelines and tighten each screw to the same torque. This helps control even load sharing among fasteners in a connection.

Q: **Do your design guides include tables for inclined screw applications?**

A: Our new CLT connections design guide has many design tables for inclined screw applications in mass timber, including ledger connections, panel-to beam connections, and floor panel to floor panel diaphragm connections. See also our Structural Screw Design Guides.

To purchase the new CLT connections design guide, click on the following link: http://www.my-ti-con.com/products/usa-mass-timber-connections-handbook

Q: **Where does the normal force come from on slide 37?**

A: The normal force is assumed to be the result of minor deformation in the screw and the wood, and the effects of eccentricity between the connected members. The normal force is not the result of pre-tensioning but rather is activated once the joint is loaded, and is derived from force equilibrium analysis at the shear plane . If the members are not loaded parallel to the shear plane, but rather, in such a way that they are pulled apart slightly, then the coefficient of friction should be set to 0. To include friction in the design model, a tight fit between the members in the connection needs to be assured. According to Kevarinmäki, (2002), the maximum gap between connected members should be 0.2D.

Q: **Can you talk longer about pretension of the screws ?**

A: When using a steel side plate, the threads lock into the wood main member, but not the steel side plate or any washers used in the connection. This means that pulling power is provided by the head of the screw bearing against the washer or the steel plate, which means that a pre-tensioning force is produced. By using a torque-clutch power tool to install the screws, even pre-tensioning is enhanced, which promotes even load sharing between the fasteners.

Q: **Any insight on long-term behaviour of screws in withdrawal?**

A: As far as long-term applications for self-tapping screws in withdrawal, designers are advised not to load self-tapping screws in withdrawal in the end grain, as the behavior in this loading direction is not well-understood and the effects of checking in wood may impact the respective withdrawal resistance. For angles above 30° to the grain, it is assumed that long term-behavior for self-tapping screws can be safely captured by the load duration factors in the building codes. Self-tapping screws tested in withdrawal at 45°

and 90° to the grain for approximately 550 days apparently showed behavior matching the "Madison Curve" (Ringhofer, 2017).

Q: **As a follow up to long-term behavior of screws. Any insight on fatigue effects in withdrawal or current research being performed?**

A: Very good question. We are not aware of any studies regarding this behavior.

Q: **Regarding the boundary conditions for Beta. Why is it limited to 45 and not up to 60?**

A: There are some design documents and studies (Kevarinmäki, 2005 for instance) that specify that angles of 60° are appropriate for the truss model design method. Most of the testing in North America has been done on angles between 30° and 45°, however, so we recommend an upper bound of 45° unless testing has been performed for higher angle configurations (it is doubtful that this is a matter of safety, although it seems reasonable to proceed with caution at this point–it is also worth mentioning that angles of 60° have been analysed in greater detail using other design models). Designers should also be aware that some stiffness models that consider axial effects are only recommended for angles at or below 45 degrees.

Q: **Could you please explain the slide 52 again? Thanks.**

A: With sufficient anchorage of the threaded portion of the screws into the wood, the screws will fail in tension under an increasing load during testing before being pulled out of the wood. Self-tapping screws are available in long lengths, so this failure mode should always be checked.

Q: **Are there any equations to account for combined shear and axial loading?**

A: Yes, and we will review two design models for combined loading in the Advanced Theory and Behavior of Inclined Screws webinar May 31, 2018.

Q: **Which are the main differences in the use of inclined screws in CLT vs solid timber?**

A: It is recommended that the wood should be loaded parallel to the grain for the most part, since this is the high strength loading direction, and also because the wood failure modes are well-understood. Inclined screws can be widely used for CLT–designers should keep in mind that the CLT should be able to carry the tensile loads based on how the screw is installed. For the most part this just means anchoring the screw into sufficient layers oriented parallel to the line of the force (keep in mind, also, that tension forces cannot be transferred between adjacent lamellas running perpendicular to the line of the force, as the edges of the boards are typically not glued). For withdrawal design it should also be noted that the relative angle between fastener axis and wood grain will alternate between 45 and 90 degrees due to the crossing layers. This change in angles has to be accounted for in the design.

Q: **Is the ideal angle 45-degrees or is it closer to 30-degrees?**

A: Most applications will be 45° degrees since this balances ease of installation, high strength and high shear stiffness. Angles of 30° can be used whenever greater strength and stiffness is required. Due to the lower angle, greater screw lengths are often required to achieve sufficient penetration into the wood. 30° screws may also be more difficult to install simply due to the shallow angle although they can be advantageous for special high-performance applications.

Q: **Can you clarify difference between α versus β angles on slides 71 and 72. Don't understand how alpha could be 90°**

A: α° is the relation between fastener axis and the wood grain orientation and β° is the relation between the fastener axis and the applied force. Most of the time, α° will be the same as β° (whenever, for instance, the timber is unidirectional, and the force is in line with the grain direction). However, for CLT, the grain direction in the crossing layers may produce an angle $\alpha = 90°$. Another example might be a ledger connection, where the wood member is mostly loaded at 90 degree withdrawal.

Q: **Can you provide the calculations utilized for the design example (using US standards)? Equations used, assumptions made, etc.**

A: Keep an eye out on our “Knowledge Base” section of our website, where the general formula will be published soon. Also, our new CLT connections design guide include a design example for most common screw connections.

To purchase the new CLT connections design guide, click on the following link: http://www.my-ti-con.com/products/usa-mass-timber-connections-handbook

Q: **The design guide for CLT reinforcing for the US does not provide a lower limit for screw penetration. The Eurocode version allows 4D minimum. The US ICC report**

only allows 8D minimum. Is there testing or documentation that warrant the use of 4D minimum penetration for CLT reinforcement in the US?

MyTiCon has performed withdrawal testing at 4D, 8D, 12D and 16D penetration depth. The reference withdrawal values in our ICC reports and design guides are applicable to a minimum penetration depth of 8D, while in Canada, our withdrawal resistance values are valid for 4D and up, since they were simply calibrated differently from the US standards. The use of 4D penetration length in the US would require a reduction factor to the reference withdrawal design values, based on an analysis of proprietary test data. If you are interested in this we would be happy to provide you with a reference value addressing the 4D penetration.

Q: **Can inclined screws be used for "passive" side lap connection between clt panels? I only would have them to have no different deflection between adjacent panels.**

A: It seems like this application is for a pulling joint. In this case, perhaps fully threaded screw or a washer head screws could be installed vertically across the half-lap joint.

Q: **Are values available for load reversal cases?**

A: Please see our new CLT connections design guide for tabulated values. You can find the CLT handbook behind the link provided http://www.my-ti-con.com/products/usa-mass-timber-connections-handbook.

Q: **What is the minimum spacing between tension and compression screws?**

A: Tension and compression screws can be placed 1.5D apart from one another in each symmetrical screw cross. Depending on where the screws cross and how long the screws are this spacing may need to be increased to assure installation without screw collision/interference.

Q: **The force acting on the timber is recalculated as tension on the screw. Why is the shear component on the screw (component perpendicular to the axial force) not taken into account? is this normally never worst case/failure?**

A: For inclined screws installed between 30° and 45° to the shear plane, peak resistances are normally attained at displacements of approximately 2-4mm, with subsequent reductions in capacity a result of a loss of the axial resistance in the screw when loaded to failure. The connection strength from the axial component is typically much higher than the shear component, and since axial strength is associated with much higher stiffness than shear strength, the axial resistance of the screw "attracts" a greater share of the load. When it comes to laterally loaded fasteners, we could define failure as displacement exceeding a certain limit or a reduction in capacity of the shear effects, for instance, but with inclined screws, the connection resistance and failure are both predominantly characterized by axial parameters at these angles, so the truss model design method is based around axial effects.

Q: **Do you have any guidelines for the screw penetration depth and penetration spacing?**

A: Screw penetration depths and spacing requirements are taken from requirements for axial loading. Please see our Structural Screw Design Guides for actual requirements with visual guides.

- A US version of the book can be downloaded: http://www.my-ti-con.com/resources/assy-american-design-guide
- A Canadian version is available at: http://www.my-ti-con.com/resources/assy-canadian-design-guide