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Advancing Timber for the Future Built Environment

TIMBER CONCRETE NODE: A NEW PARADIGM FOR POST AND BEAM TIMBER CONNECTIONS

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ABSTRACT: Post and beam timber connections that cannot be realized with direct timber-to-timber bearing traditionally rely on metal hangers to transfer load from the beam to the column. Metal hangers must be entirely concealed within the timber or otherwise covered with supplemental fire protection to retain their load carrying capacity during a fire event. Very tight tolerances are therefore required to fit the components together to protect the metal hangers, or gaps must be sealed with intumescent caulk/tape to provide supplemental protection. The Timber Concrete Node (TCN) provides an alternative to metal hangers, by using a reinforced concrete bearing node to connect timber post and beam structures. The TCN can be left fully exposed to view and to fire, or it can be partially or fully covered by timber depending on the architectural vision. By leveraging a simple kit of parts and affordable materials, the TCN can be used to make easy, cost-effective, and high-capacity connections in mass timber structures. The product has undergone structural load testing and fire testing, and it has now been used in a pilot demonstration project in Vancouver, BC.

KEYWORDS: mass timber, precast concrete, concrete node, beam-column, connection testing

1 – INTRODUCTION

Mass timber construction has rapidly grown in popularity over the last two decades as one of the primary sustainable construction materials that aims to reduced embodied carbon in the built environment. One of the main barriers preventing even more widespread adoption of mass timber is cost and installation complexity; despite efficiencies gained from prefabricated components, mass timber construction typically comes at a cost premium compared to concrete, steel, and light-wood framing. This is compounded by metal hanger connections which typically require extremely tight construction tolerances and therefore can lead to installation issues on site when parts are not properly aligned.

The Timber Concrete Node (TCN) is an alternative to traditional metal hangers which aims to solve these problems. The TCN as shown in Fig. 1, provides an extended bearing area for timber beams via a concrete node that cantilevers from the face of the supporting member. Concrete is inherently fire resistant when adequate cover and thermal mass is provided to protect the reinforcing steel. It can therefore be left exposed in the finished condition, which increases the allowable construction tolerance between the building elements. With increased tolerance, connections can be assembled more rapidly and with fewer clashes. Concrete is also an affordable construction material, and it is readily scalable, so the TCN connection can be used for small beams and purlins as well as the largest and heaviest loaded timber girders seen in mass timber construction today. The small volume of concrete used in TCN connections can help to enable more buildings to be constructed from mass timber and therefore have a significant reduction in overall embodied carbon.

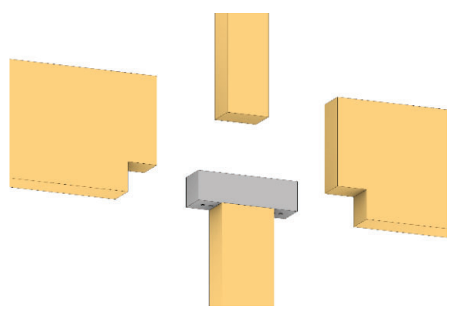

Figure 1 – TCN Exploded Components View

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2 – BACKGROUND

The most economical connection in post and beam timber construction is direct bearing of the timber beams onto the timber columns. This is commonly done at roof levels, but at floor levels it is not typically possible to support the beam in bearing on the column alone, since the column must also transfer axial forces from the storey(s) above. Therefore, metal connectors or hangers are commonly used to support the beam off the face of the column, while allowing the axial load of the column to be transmitted through the floor level without interruption. To retain their capacity during a fire event, steel or aluminium hangers must be concealed within the timber or covered with supplemental fire protection because they rapidly lose strength and stiffness at elevated temperatures. Tight tolerances must be maintained between the timber and metal interfaces to prevent a fire's heat from prematurely reaching the metal connectors. This makes the detailing, fabrication, and installation of metal connectors for timber structures challenging and relatively high cost.

The TCN has been developed as an alternative connection solution in place of traditional metal hangers. In partnership with the University of British Columbia (UBC), Ultra-High Performance Concrete (UHPC) nodes were analysed using ABAQUS software and physically tested at Fast + Epp's Concept Lab [1, 2]. Numerical and analytical studies were then conducted to validate the software model against the experimental results.

3 – PROJECT DESCRIPTION

In parallel with the UBC research and analysis, Fast + Epp engineers have continued to develop design ideas for a concrete node that could be made as simply and as cost-effectively as possible. The TCN takes the form of a rectangular prism to minimize the size the concrete node, and to allow the depth of the node to be independent of the depth of the attaching beams. Starting from a rectangular form, the TCN can be reinforced with hooked rebar, or it can be split into 2 separate halves which are connected by threaded rods that prestress the TCN while also providing flexural reinforcing. The TCN will typically be a precast component made from self-consolidating concrete to provide excellent surface quality, dimensional precision, and factory-controlled QA/QC procedures. TCNs can be fabricated with conventional normal-weight concrete, lightweight concrete, or UHPC mix designs, and will usually include fibre reinforcing for toughness and durability.

TCN connections can be either:

- Fully Exposed to view (Fig. 2a)
- Partially Concealed by the timber column (Fig. 2b), or
- Fully Concealed by the timber beams and column (Fig. 2c).

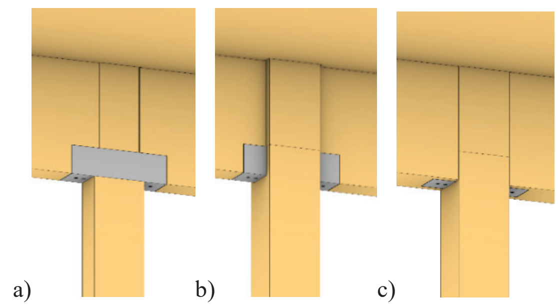

Figure 2 – (a) Fully Exposed, (b) Partially Concealed, and (c) Fully Concealed TCNs

One of the unique functional advantages of the TCN is its versatility, allowing for a wide range of connection possibilities for various applications. It can be used as a one-sided or a two-sided connection, and it will typically also function as the column splice connection (Fig. 3). Alternatively, it can be inserted through a hole in a continuous multi-storey column, or through a hole in a timber girder or CLT wall.

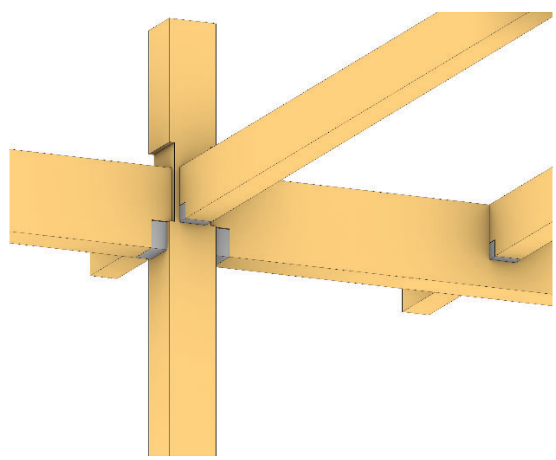

Figure 3 – 2-way TCN Connection Example

4 –DESIGN PROCESS

There are a few considerations that may govern the structural design of the TCN:

1. Perpendicular to grain bearing stress on the bottom of the beam
2. Bending of the concrete node
3. Stress on the notched beam section

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These mechanisms work against one another because increasing the length of the TCN will increase the bearing capacity, but it also increases the eccentric moment that must be resisted. Similarly, decreasing the cantilever length will decrease the eccentric moment but drive up the perpendicular to grain bearing stress. Deeper nodes have much higher bending resistance, but they also weigh more and are more likely to require notch reinforcing screws. The most economical connection design must therefore find a balance between the different load bearing mechanisms, while keeping the TCN compact so that it is easy to handle during construction. An economical and efficient connection will also minimize the number of self-tapping screws required for notch reinforcement or bearing reinforcement.

The steps required when designing a TCN connection can be summarized as follows:

1. Determine the beam reaction(s).
2. Select a preference between fully exposed, partially concealed, or fully concealed nodes.
3. Select the widest TCN that will work for the selected node type to maximize the perpendicular to grain bearing resistance.
4. Determine the required bearing length to resist the perpendicular to grain bearing stress.
5. Analyse the bending moment generated from the eccentricity between the centroid of the load applied by the beam and the centroid of the load resisted by the column face.
6. Select the appropriate TCN depth and steel reinforcement to resist the applied moments.
7. Check the moment capacity of the selected TCN for the fire load case, which will have reduced loading but increased eccentricity due to charring of the supporting column face.
8. Check the shear capacity of the TCN design for both the governing gravity load case and the fire load case.

At this point the size of the TCN is fully determined, and the designer can consider if the size and weight meet their targets for ease of installation. If not, 2 key methods can be used to decrease the size of the TCN:

A. Add fully threaded bearing reinforcement screws to decrease the required bearing length. This will decrease the overall node length as well as the depth because the bending moments can be dramatically reduced.
B. Extend the beam partially over the supporting column. Retain sufficient column area to transmit the axial loads from the floors above, while again decreasing the length of the TCN and the moments that must be supported.

To aid with both the design and supply processes, a set of standard TCN sizes has been developed – see Table 1. From this table, designers can select the appropriate TCN size to support the loads from their projects. Fast + Epp will also provide engineering support for TCN connections when the design is delegated. A parametric design tool has been developed to rapidly analyse, select, and visualize different TCN options in order to choose from the standard sizes or to create a custom size if required. While custom sizes are relatively easy to create in precast concrete, selecting from the standard node sizes decreases formwork costs and lead times to ensure the most economical connection supply.

Table 1 – TCN Ultimate Load Capacity

TCN Width [mm] →	**127**	**171**	**210**	**260**	**311**	**362**
TCN Depth [mm] ↓	**Ultimate Load Capacity (per Beam End Reaction) [kN]**					
114	158	208	260	317	375	432
152	178	249	304	373	441	509
191	187	286	348	428	508	587
229	199	303	367	466	574	664

Assumptions: 1) LWC (1840kg/m3) with f'c = 40MPa minimum; 2) TCN reinforcing = 10M or #4 bars with As = 1.2-3.5%
3) f_{cp} = 7MPa (DFir) with 10x200 bearing reinforcement screws; 4) Each glulam beam is notched into column face by 50mm
5) TCN overhang = TCN depth; 6) TCN sizing is based on North American glulam sizes

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5 –RESULTS OF PILOT PROJECT

5.1 DESIGN PARAMETERS

The first project to employ the TCN connection is the Marpole Community Centre in Vancouver, Canada. As a pilot demonstration project, three locations of metal hangers were substituted with concrete nodes.

The governing loads for the selected locations were:

- Dead = 3.7 kPa [77 psf]
- Live = 4.8 kPa [100 psf]
- D + L = 182 kN [41 k]
- 1.25D + 1.5L = 253 kN [57 k]

The TCNs designed for this project had the following parameters:

- Width = 216 mm [8.5 in]
- Depth = 190 mm [7.5 in]
- Length = 648 mm [25.5 in]
- Weight = 57 kg [125 lbs]
- Concrete type = UHPC
- f'c = 90 MPa [13ksi]
- FRR = 1 hr

Two screws were used to fasten the TCN to the column, and two screws were used to fasten the TCN to the beam (Fig. 4). These screws create a positive connection between the members but do not actually support beam or column loads. There are also four total notch reinforcing screws used for the TCN detail on the pilot project.

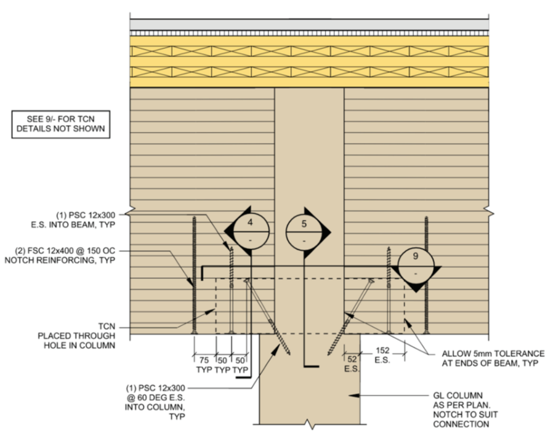

Figure 4 – TCN Assembly Detail

5.2 STRUCTURAL TESTING

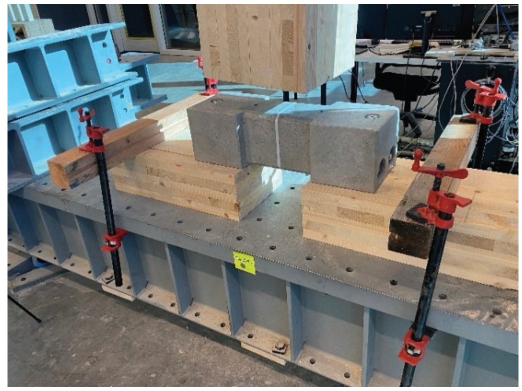

Figure 5 – Structural Testing with Timber Supports

Three identical TCN samples were fabricated for the purpose of strength and durability testing in Concept Lab. The governing design load of 253 kN per side is equivalent to a bending moment of 21.4 kN-m (189 k-in). Two samples were proof loaded in three-point bending using timber supports to replicate the support conditions from the pilot project (Fig. 5). These samples were proof loaded up to 250kN per side, or 500kN total which is the maximum load capacity of the self-reacting test frame in Fast + Epp's Concept Lab. Steel roller supports were then inserted to increase the load eccentricity and amplify the applied bending moments (Fig. 6). A maximum moment of 41.3 kN-m (365 k-in) was applied, and the specimen failed due to rupture of the reinforcing steel rods (Fig. 7). The failure load therefore represents a 1.9x overstrength compared to the design loads, or a total safety factor over 2.6x for the project, including the load factors.

Figure 6 – Structural Testing with Steel Roller Supports

Figure 7 – TCN After Fracture of the Steel Tension Reinforcing Rods

Following the three-point bend tests, the TCN sections with the least amount of damage were subjected to impact testing to demonstrate the resiliency provided by steel reinforcing fibres. One sample without steel fibres was tested in comparison with the reinforced TCN section. The samples were dropped onto a steel beam from progressively higher heights, starting at 100 mm and increasing to 3500 mm. The sample with steel fibre reinforcing had chipped corners and visible cracks but retained its structural integrity after the 3500 mm free fall onto the steel beam. The sample without reinforcing fibres split in half after a free fall of just 600 mm.

5.3 FIRE TESTING

Following the structural load testing, one node was brought to QAI Labs in Burnaby, BC for 1-hr fire testing in a pilot scale furnace to verify the FRR of the TCNs used in the Marpole Community Centre. The node was assembled with surrounding timber beams and column to replicate the wood cover and the exposed concrete surfaces from the condition seen in the pilot project (Fig. 8). The temperature curve of the fire test followed the standard 1-hr temperature curve from CAN/ULC S101-14 *Standard Methods of Fire Endurance Tests of Building Construction and Materials* (Fig. 9).

A thermocouple wire was installed under the nut on the reinforcing rods to measure the temperature of the reinforcing steel throughout the test. The sensor was connected by wire to a computer that recorded the test data. The wire was insulated to protect it from fire, but the technicians noted that wires in similar setups did not last for the full 1-hr duration in previous tests, due to failure somewhere along the protective insulation.

Figure 8 – TCN and Timber Assembly Post-Fire

During the test, occasional popping sounds from spalling of concrete were observed. The temperature of the steel bars was continuously monitored and remained below 50°C for the first 40 minutes. Around the 42-minute mark the temperature from the thermocouple began to rise rapidly, ending at a peak of 350°C (660°F) (Fig. 9). This remains below the critical temperature for steel, as the Modulus of Elasticity is reduced by a factor of 0.75 and steel yield strength is unreduced (i.e. 1.00 factor) at a temperature of 350C [3].

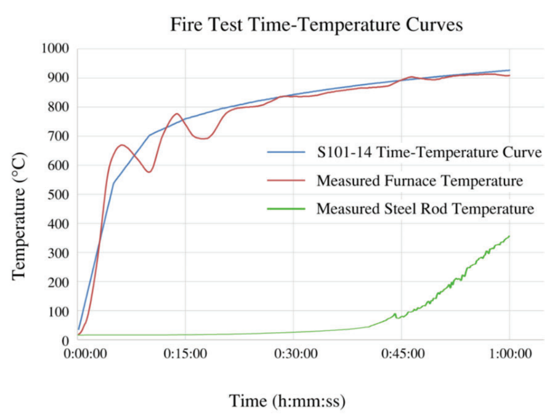

Figure 9 – Furnace and Steel Rod Time Temperature Curves

The rise in steel temperature may be due to one of the following reasons:

a. Failure of the protective insulation around the thermocouple cable. Or,

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b. The thermal mass of the TCN gradually warming until the reinforcing rods in contact with the concrete began to warm. Or,
c. Hot gases reaching the exposed ends of the steel reinforcing bars. This is considered unlikely because the gap between the concrete and timber remained 5 mm throughout the test, so there is no apparent mechanism to cause the sudden increase in temperature.

Further fire testing will be conducted to verify TCN performance in a 2-hour fire condition. It is planned to utilize alternative concrete mix designs and additional thermocouples cast in the concrete to better understand the governing factors for TCN fire performance in durations longer than 1 hour.

5.4 POST FIRE STRUCTURAL TESTING

When the fire test was complete, the assembly was subject to water spray until the fire was extinguished. Hotspots were monitored and sprayed with more water to prevent continued smouldering. The pieces were disassembled the following week and returned to Concept Lab for post-fire structural load testing.

The burnt TCN was assembled with timber supports to replicate the amount of charring that occurred during the 1-hr fire test. The node was then loaded in three-point bending up to the actuator capacity of 500kN. Despite the spalling and cracking of the concrete node from the fire test, no additional damage was observed during the post-fire load test (Fig. 10). This demonstrates that the TCN retained at least 1.4x the required load-carrying capacity after the 1-hr fire compared to the required D + L loading.

Figure 10 - TCN Following Post-Fire Structural Testing

5.5 INSTALLATION

Three TCN connections were installed at the new Marpole Community Centre in September 2024 (Fig. 11 and 12). The columns were installed first by tower crane, and then the TCN connections were installed separately by a single worker on a scissor left. This workflow ensures that additional crane time is not required to lift the TCN connections into place. Another alternative installation strategy could be to pre-install the TCN connections onto the timber columns and then use the TCN as the column lifting device with slings choked around the concrete node.

Next, the timber beams were installed by tower crane, and the beam slipped easily into place on the TCN. It was noted by the installation team members that the additional tolerances provided by the TCN connection facilitated easy assembly and that they wish to see additional projects use the TCN as the primary connector type.

Figure 11 – TCN Installation at Marpole Community Centre

5.5 NODE FABRICATION AND SUPPLY

The standardization, economical fabrication, and supply of TCNs has been paramount to creating a successful product that can be specified by designers around the world. Care has been taken to consider the size of the TCN in relation to standard glulam beam and column sizes that are available both in North America and in Europe. Timber fabricators and installers have been consulted to ensure the details associated with the TCN are easy to fabricate, and that the components can be joined with a limited number of fasteners. As noted, there are just four screws joining the TCN to the timber beam and column, and none of those screws are supporting load in the typical condition. In contrast, the metal hangers that were replaced on the pilot project were originally designed with 208 screws, all of which are directly supporting the transfer of gravity load from beams to column. These aspects create significant advantages for the TCN compared to the traditional metal hanger products.

The TCN will be precast at facilities close to each construction site to minimize shipping costs (both dollars and environmental impact). Trusted prefabrication partners will be developed regionally to ensure that reusable moulds can be employed for the standard node sizes to facilitate node production at scale.

For the pilot project, Szolyd Concrete Corp (Szolyd) were contracted to fabricate the TCN connections. Szolyd are mould making experts and have extensive experience casting custom UHPC components, so they were brought on board to ensure that the surface finish and dimensional accuracy of the TCN was of the highest quality. Together, several aspects of the mix design were carefully considered, including using locally sourced and recycled aggregates. A non-profit consortium has since been formed, with Fast + Epp, Szolyd, Light-house, Seacork Studio, and UBC as founding members with the aim of exploring and creating sustainable construction products to maximize the use of nature-based materials. This effort includes the continued development of the TCN connector to help create the most economical mass timber connections possible.

6 – CONCLUSIONS

A novel connector for mass timber structures has been developed in the form of a precast concrete node (a.k.a the Timber Concrete Node, or TCN). The design process has demonstrated that concrete can be used to create economical, high-tolerance, high-capacity, and fire-resistant connectors in a variety of sizes, forms, and use cases. Structural testing, including three-point bend testing, impact testing, and 1-hr fire testing has been conducted to verify the performance of the TCN connections in the initial pilot project (Figs. 11 and 12). Through the design and testing process, the TCN connection has proven to be a viable solution for simplifying mass timber connections. The product has been standardized for mass production, has a patent-pending status, and is ready to be specified as an alternative to metal connectors for post and beam mass timber structures. Engineers at Fast + Epp are working on specifying TCN connections for suitable projects currently in design, and will help support other engineers to specify TCN connections as a delegated design item.

Figure 12 – Installed TCN at Marpole Community Centre

7 – REFERENCES

[1] A. Abdallah, M. Shahnewaz, C. Dickof, and L. Tobber. (2024). "Production of UHPFRC nodes for timber structures in the Canadian West Coast: Lessons learned" In: Canadian Society for Civil Engineering Conference Proceedings.
[2] A. Abdallah, M. Shahnewaz, C. Dickof, and L. Tobber. (2024). The behaviour of precast UHPC nodes for timber structures: A numerical study. 4th International Conference on New Horizons in Green Civil Engineering, NHICE-04, Aug 26- 28, Victoria, BC, Canada.
[3] AISC Steel Design Guide 19, "Fire Resistance of Structural Steel Framing" Table X.1).

https://doi.org/10.52202/080513-0642