

Understanding Tolerances in Prefabricated Timber Construction

Speaking the Same Language from Design to Site

As prefabrication and hybrid timber systems become more common, the phrase “within tolerance” can mask differing assumptions among designers, manufacturers, and installers. Components may meet standards yet still fail to fit on site, leading to delays, rework, and disputes.

This paper introduces a tolerance framework for prefabricated timber construction, clarifying how tolerances function across design, fabrication, and assembly. It distinguishes between material limits, manufacturing capabilities, framing deviations, installation allowances, and in-service movement, and outlines how key concepts work together to support constructability and performance.

By establishing a shared language and workflow, the framework helps align design intent with manufacturing and site conditions. The result is more predictable assembly, reduced risk at critical interfaces, and greater confidence that systems will perform as intended.

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1. Discussion Overview

Design and Construction professionals often say, “it’s within tolerance.” Very few mean the same thing.

Engineers quote CSA or CISC limits. Architects think about visual gaps. Manufacturers talk about CNC accuracy. Installers think about fitting things on-site. Prefabrication puts all of that on a collision course. When the language around tolerance is vague, complex assemblies don’t fit, schedules slip, and everyone blames everyone else.

This paper lays out a tolerance framework for prefabricated and hybrid construction, using clear, practical terminology for multidisciplinary project teams. It includes:

- » Four core tolerance classes: Material Specification Limits, Manufacturing Standard Capabilities, Framing/System Deviation, and Installation Allowance.
- » One primary fit concept: Clearance Fit, supported by explicit Designed Fitment Gaps.
- » Two management concepts: Critical to Fit (CTF) features and Critical Dimensions (CDs) that control whether systems assemble and perform.

The objective is simple: have architects, engineers, manufacturers, and installers talk about tolerances in the same way, early enough, so that prefabricated components that should fit, do fit. At the end of this process, you will see that there are various terms for what is commonly called “tolerance” and that these refer to very distinct components.

2. Why Tolerances Matter More Now

The shift from site-built construction to offsite prefabrication has made tolerance management a critical consideration. Given the scope and cost of today’s projects, preventable project delays can significantly affect overall project viability.

Key Challenges

- » Mass timber, CLT, steel, and façade systems are CNC-fabricated to millimetre-level accuracy.
- » Offsite assemblies (façade panels, MEP racks, modules) have very little adjustability once they arrive.
- » Schedules are tighter and labour is more expensive, so rework erodes project viability quickly.

The result is that systems may meet product standards but may still not fit cores, ledgers, or final site placement. The root cause is simple: different parties use the word tolerance for different things. The fix starts with a clear, shared set of definitions.

3. Shared Tolerance Terminology

3.1 Material Specification Limits

Material specification limits are the dimensional ranges built into standards such as CSA O122 (glulam) and PRG-320 (CLT). Once you reference these standards in a specification, you’ve accepted those ranges as “in spec.”

Example

- » **Glulam to CSA O122**
 - » Length: ± 6 mm for the first 6,000 mm, plus ± 3 mm per additional 6,000 mm, to a max of ± 19 mm.
 - » Depth: ± 0.4 mm per lamination, up to ± 6.0 mm.
 - » Width: ± 2 mm.

Why it matters

These limits define what a supplier can legally deliver and still be considered compliant. They do not guarantee that a particular interface or joint will work. Designers still need to translate these limits into realistic fitment gaps and details.

3.2 Standard Manufacturing Capabilities

Standard manufacturing capability tolerances describe what a specific supplier can reliably achieve and are typically tighter than the product standard.

A modern glulam or CLT fabricator, using CNC processing and decent process control, will often hold member length and connection features to approximately ± 2 mm, even though the material standard would allow greater variance. This is driven by machine capability, internal quality assurance (QA) processes, and competitive positioning. It can also be noted that different CNC machine tool features, such as a chainsaw bar vs. an endmill, carry different manufacturing tolerances.

These achievable tolerances need to be clearly published or stated by the supplier, brought into the contract, and reflected on approval drawings for critical components.



If a detail requires ± 2 mm on a connection feature, but your specification only references CSA O122 or PRG-320 and never binds the supplier to their tighter manufacturing standard, you have created a gap between design intent and contractual reality.

3.3 Framing / System Deviations

Framing or system deviation tolerances describe how straight, plumb, level, and on-grid the primary structure is once built. They are based on concrete, steel, or timber erection standards and project quality plans, and they apply at the building scale, not at individual connections.

Typical examples are a core wall that leans a few millimetres over its height, a slab edge that wanders relative to the grid line, or column lines that drift over several bays. These deviations are often much larger than the CNC tolerances on prefabricated parts. Prefabricated systems can have fit issues because design and fabrication assumed a perfect geometry, while the actual structure could be 10–15 mm off position and still be considered acceptable within standards of practice.

3.4 Installation Allowances

Installation allowance tolerances describe the additional variation introduced when components are assembled onto the as-built frame or onto each other. Even if the frame and every part were dimensionally perfect in isolation, the act of lifting, aligning, shimming, and bolting can introduce additional variation.

For example, a steel plate bolted to the end of a glulam beam will pick up small amounts of extra length from minor waviness in the timber, variations in coating thickness on the plate, and the plate bearing on local high spots when the bolts are tightened. Repeated across multiple members, those small installation effects can add up to a significant extra length beyond what the model assumed.

Installation tolerances are not a contractor failing; they are the inevitable result of real materials and real handling. They need to be explicitly allowed for, on top of framing tolerances, in any serious fitment design.



Figure 1. Hundegger CNC Machine
Photo credit: Whirlwind Consultants

3.5 Performance Life-Cycle Tolerances

Finally, there are tolerances associated with how much movement a system can sustain over its service life and still meet performance requirements.

Moisture content changes will cause CLT and glulam to shrink across the grain as they dry in service. Concrete and timber will creep. Steel components and façade systems will move relative to temperature changes. Environmental loads such as wind or seismic also cause movement over the building life. All these movements need to be accounted for in the specification to ensure adequate performance. Seals and gaskets are rated for a certain range of joint movement; this future movement needs to be quantified and communicated.



4. Clearance Fits and Designed Fitment Gaps

A Clearance Fit means that, after all realistic tolerances are considered, there is still a small but reliable gap so parts can be assembled without requiring excessive force or rework. In prefabricated work, this should be the default at interface zones such as knife plates into glulam slots and anchors into slotted holes, unless you are explicitly designing a bearing or interference condition. The gap provided must absorb all the types of tolerance discussed previously, while still ensuring structural, fire, acoustic, weather, and visual performance.

The designed fitment gap is simply the Clearance Fit written as a dimension range on the drawing (for example, 2 mm). It should not be derived from summing worst-case tolerances but should be based on realistic tolerance ranges and a target high probability that the joint remains in clearance, not interference.

The designed fitment gap is where the real negotiation needs to occur. It is the number that architects, engineers, manufacturers, and installers should be debating and aligning on for each critical interface zone, rather than relying on vague statements about “tight tolerances” or “good quality control.”

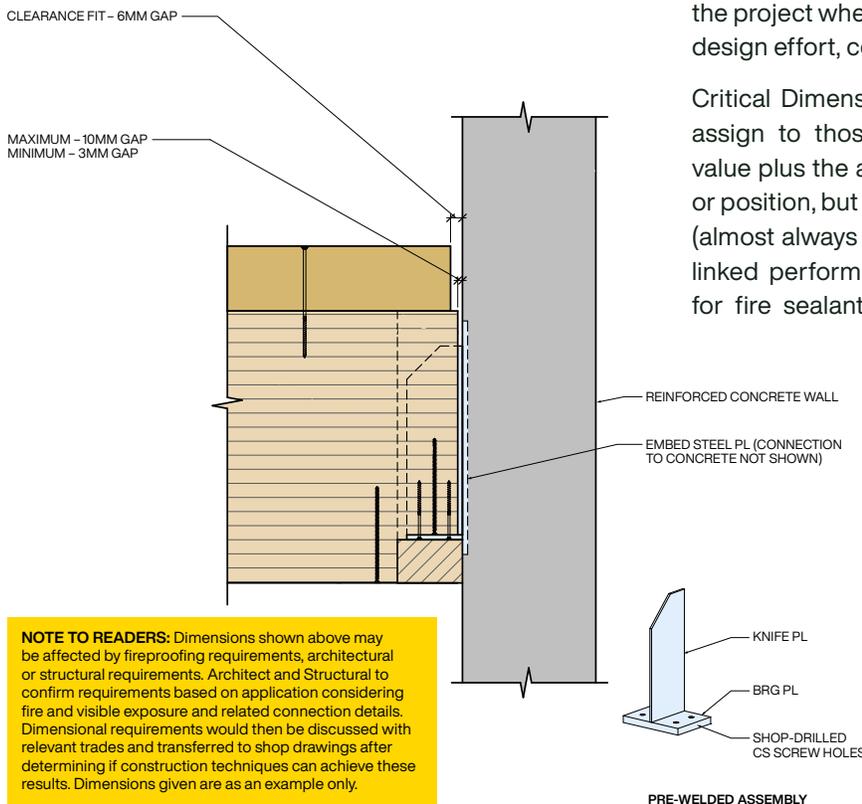


Figure 2. Steel knife plates fit into prefabricated glulam assemblies include clearance fits around steel to ensure installation.

Photo credit: Whirlwind Consultants

5. Critical to Fit Features and Critical Dimensions

Critical to Fit (CTF) features are the few dimensions or interfaces where, if they drift out of tolerance, the system simply does not go together without cutting, drilling, or other rework. Consider column base bolt locations relative to grid, the clear distance between two fixed supports that must receive a prefabricated beam, the size and position of a pocket for a module, or the slab edge relative to a curtainwall anchor zone. These are the joints that delay the project when they’re wrong, so they warrant increased design effort, coordination, and QA focus.

Critical Dimensions (CDs) are the specific numbers you assign to those cumulative CTF features: the nominal value plus the allowable range. A CD defines not just size or position, but the tolerance band and intended fit regime (almost always a Clearance Fit in prefabrication), and any linked performance limits such as minimum joint depth for fire sealant or maximum visible gap for aesthetics.

Figure 3. Sample Detail showing dimensions for design intent and trade review.

Photo credit: Whirlwind Consultants



For example, you might define a CLT panel end gap to a concrete core as 6 ± 2 mm, in service; a smaller gap risks causing binding during installation, while a larger gap undermines fire and acoustic performance. That range is not cosmetic; it is the quantified outcome of the combined tolerance picture and the performance requirements.

An interesting note in this example is that the concrete core likely has a tolerance specification of ± 25 mm, thus in this instance a site survey is required to ensure connections to concrete allow for the in-situ location, or a Critical Dimension is required that is controlled by project QC processes to ensure conformance. A CTF dimension may be labelled internally on a shop drawing, while a CD may be part of broader contract documents on submissions and shared with broader teams.

The CTF (Critical to Fit) is the specific shop level dimension on a single component portion.



Figure 4. Column pre-assembly, measured for Critical Length Dimensions and Moisture Content prior to shipment.
Photo credit: Nicholas Sills

The CD (Critical Dimension) is the dimension that matters and is formerly controlled on contract documents and measured in the field.

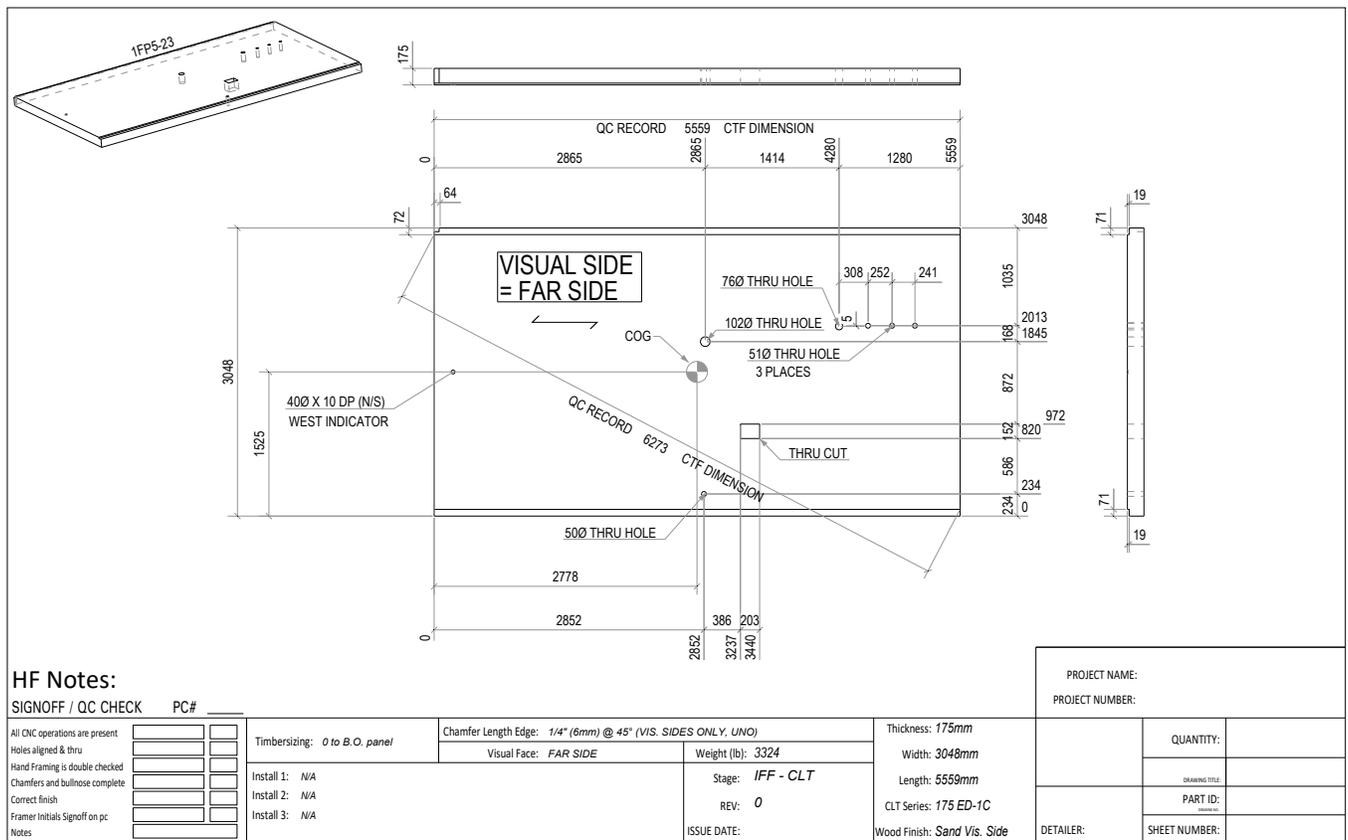


Figure 5. Critical to Fit Dimensions marked on a shop drawing for QC Review.
Photo credit: Structurlarm



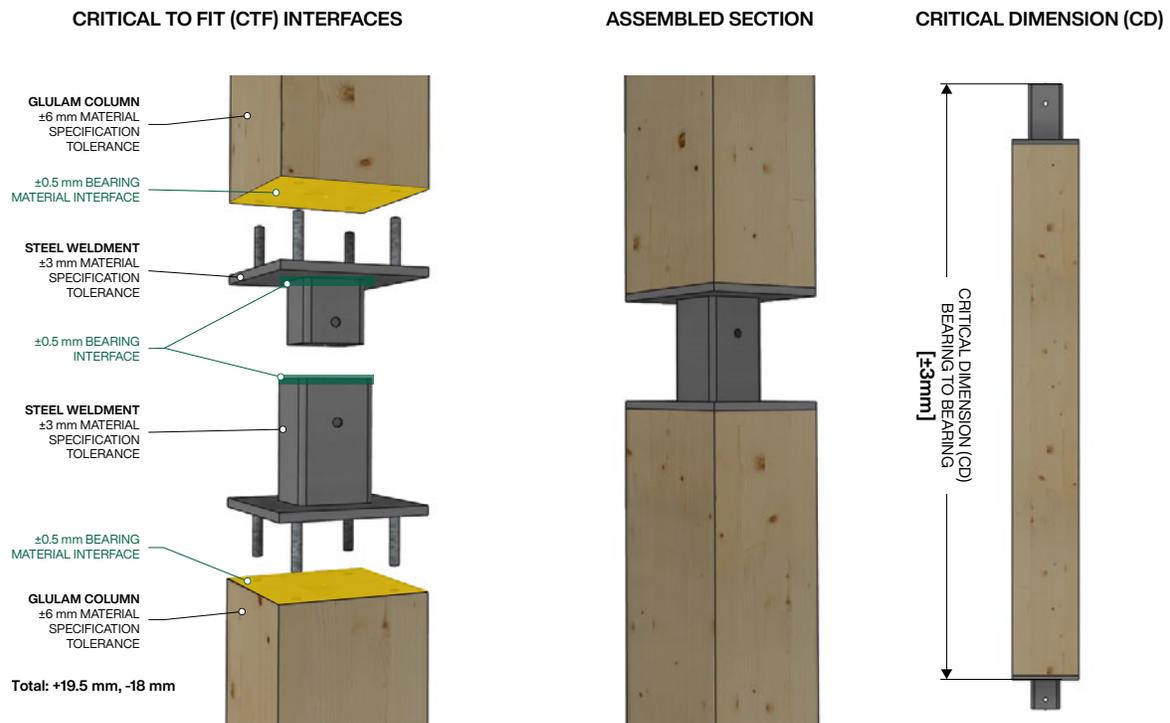


Figure 6. Relationship between CTF and CD in multi-storey glulam column.
Photo credit: Whirlwind Consultants

5.1 Critical Dimension Example

The example above showcases Critical to Fit (CTF) interface zones culminating in the Critical Dimension (CD). In this example, columns are stacked bearing surface to bearing surface over a multi-story building. If you add the individual component tolerances throughout the assembly, you end up with +19.5 mm and -18 mm tolerance specifications. For most multi-story buildings this would be beyond acceptable for constructability. To ensure fitment and limit liability for project team members, a Critical Dimension has been added to an agreed upon

specification tolerance. This means that the installers, design team, and manufacturer have all agreed to a tighter tolerance on these elements per contract documents, in this case ± 3 mm.

The manufacturer would be expected to implement additional quality control mechanisms to ensure deliveries meet this specification. They may also be required to document these Critical Dimensions in some additional form of quality control or contract document to help ensure success for the project.

Common Areas for Application

- » Assembled beam and hanger systems fit between two columns or beams
- » Interface zones between lateral core systems and the rest of the building
- » Stackable column to column connections
- » Diagonal brace frame element assemblies
- » Prefabricated envelope panel systems



Key Terminology

Material Specification Limits

The allowable size and shape variation defined by codes or product standards for a given material (what is legally “in spec” when you order it).

- » Often termed “Tolerance”

Standard Manufacturing Capability

The level of dimensional accuracy a specific manufacturer can reliably achieve in production, typically tighter than the code or product standard.

- » Often termed “Tolerance”

Framing / System Deviation

The amount by which the built primary structure (cores, slabs, columns, grids) differs from its theoretical, modelled geometry.

- » Often termed “Tolerance”

Installation Allowance

The extra space or dimensional slack intentionally provided to account for real-world variation when components are assembled on site.

- » Often termed “Tolerance”

Clearance Fit

A designed condition where, after all tolerances are considered, a positive gap always remains so parts can be assembled without forcing or rework.

- » Often termed “Tolerance”

Critical to Fit

A feature or dimension where being out of tolerance directly prevents prefabricated components from fitting together without rework. Often identified on individual trades shop drawings.

Critical Dimensions

The specific numerical targets and tolerance bands assigned to Critical to Fit features and other key joints that control assembly and performance. Often identified on contract documents such as architectural or structural drawings.

5.2 From Standards to CTF and CD

This is the workflow that turns broad tolerances into specific Critical to Fit features and Critical Dimensions.

1. Start from standards

- » Note material specification limits (CSA, PRG-320, steel/concrete tolerances).

2. Overlay real manufacturing capability

- » Confirm what each supplier can actually provide (e.g., ± 2 mm on CNC-cut members).

3. Add installation allowance and life-cycle movement

- » Include expected on-site variation (lifting, shimming, debris).
- » Factor in shrinkage, creep, and thermal movement where relevant.

4. Identify Critical to Fit (CTF) features

- » Mark the joints where misalignment stops assemblies from fitting (cores, ledgers, key supports, envelope interfaces).

5. Assign Critical Dimensions (CDs)

- » For each CTF feature, set a nominal value and tolerance band (usually a Clearance Fit range) that still meets performance requirements.
- » CDs can be denoted on submission documents for prefabricated assemblies.

6. Capture in a tolerance / interface matrix

- » Put all CTF features and their CDs in one table that is referenced by drawings, specs, and shop drawings so every party is working to the same numbers.



6. Making the Industry Speak the Same Language

This strategy is not a new idea. It is simply bringing the level of tolerance thinking that already exists in many other industries into mainstream building practice in a simplified, usable form.

For project teams, the practical steps are simple.

1. Stop using the word “tolerance” without identifying which type you mean.
2. Define Clearance Fits with designed fitment gaps at all critical interfaces, not just at typical details.
3. Identify Critical to Fit features explicitly and attach Critical Dimensions to them.
4. Make sure manufacturer capability and frame tolerances are honestly reflected in those numbers.

If you do that, you may still encounter defects and field issues. But you will stop having situations where every party is “within tolerance” and the building still doesn’t fit. You will also have a shared language that clarifies expectations and supports clear, fair accountability grounded in technical criteria rather than opinion.

Taken together, these practices provide a strong foundation for successful prefabrication. Applied early, they align design intent with manufacturing reality and site conditions, reduce risk at critical interfaces, and support predictable assembly in the field. Just as importantly, they replace ambiguity with coordination, enabling multidisciplinary teams to focus their effort where it matters most: delivering buildings that fit, perform, and meet expectations the first time.

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