ENGINEERING TIPS AND TRICKS
STRUCTURAL

Use the following tips and tricks to support the design of structures - both in your work and when you are checking others' work.

The purpose of these tips and tricks is to help you avoid failure by understanding some basic rules of thumb and simplifying a complex problem to compare your understanding to a computer output. By working heuristically (applying rule of thumb) to quickly estimate ballpark solutions, you can understand whether or not something (such as a computer model) is accurate.

We have developed this document to share knowledge that is often not written down, so we can all benefit from the years of on-the job-experience and learnings of senior engineers.

We have intended it to complement your own experience and expertise. Note: these tips and tricks still rely on a level of capability and awareness of where parameters lie. Casually designing without understanding these may lead to an engineering failure, so you must still check your work carefully.

Note: you and your checking engineer must have sufficient experience to understand using rules of thumb and their parameters. You must state these where you make assumptions so they stand out to any checking engineer. You may need to supplement this template with additional information depending on the project's scope.

GENERAL DESIGN TIPS

Following are some tips to apply to the planning, design and detailed drawings for all structures.

- **Always develop a draft design features report (DFR) as part of your planning**. The DFR summarises the key features you are proposing or including in your proposal and gives something tangible to get feedback and approval before doing extensive calculations or modelling.
    - Always plan loadings, load paths, and potential issues and seek approval from a senior team member before proceeding with the design. Writing out the DFR first helps you understand the project and clarify it in your mind. If you can't write down a concise summary of the structure, it's because you don't understand it well yet. The DFR is structured to help you.
- Remember that **staged construction can greatly influence analysis results**, not just for very tall buildings.
    - Highlight critical details and assumptions about the build sequence or method in your DFR. Highlighting those details is especially important where build or installation sequence is an important design consideration, such as temporary works, seismic strengthening or demolition.
- **Develop design documents so that a contractor can build the project!** A design is not an academic assignment – so think about how that happens and do not merely provide drawings of a completed project.
    - **Draw EVERYTHING on the details**. Often, the bits 'omitted for clarity' are where it goes wrong. Ideally, show these details in grey, or dotted, so give thought to how they interact with the rest of the structure.
    - Understand that **different materials have different tolerances**, and the design must accommodate these. For example, contractors cannot build concrete to the same tolerances as steel.
    - When designing beam/column joints, take care to ensure the contractor can build the details. Note: in timber design, the connection detailing can be the determining factor when sizing the member.
    - Think about access for the work to happen: e.g. can the contractor drill the hole or place the bar?
- Using a ductile design philosophy reduces design actions and can increase deflections since member sizes can reduce, but SLS loads don't change.
    - Remember that larger deformations have the potential to lead to more damage or failure, so invest time and expertise proportionate to the potential for damage.

CHECKING OTHERS WORK

Checking other people's work is invaluable both for internal quality control and as a learning tool. How easy is it to check someone else's work? Is there a DFR? Are calculations backed up by simple diagrams explaining the math? Reams of pages of calculations are almost impossible to check, but a good design tells a story. Computer analysis should always be backed up by a quick hand calculation making sure the two are aligned.

Here are some considerations when checking and providing feedback on colleagues' structural design.

- Is the deflected shape consistent with that expected?
- Are the moment diagrams consistent with that expected and align with the deflected shape?
- Is the building weight about right?
- Do the seismic base reaction equal the hand calculated base shear? If not, why not?
- Are beam and column deflections within limits? Is there stiffness compatibility between different elements?
- If most beams and columns are the same size, why are others not?
- Are beam/column sizes consistent with rules of thumb?
    - Do the connections and bracing provide a continuous load path to the foundations for lateral load in any direction?
    - Do the connections details match the assumptions used in the analysis? i.e., will they behave as modelled? Check for fixed ends when notionally pinned and vice versa.
    - Are the primary structural members similar to those in similar projects?

DESIGNING WITH DIFFERENT MATERIALS

Engineers need to know a lot about many materials, how they are applied and work together to design safe and reliable structures. Here are some points to consider.

CONCRETE + REINFORCED MASONRY

Always think, how is the contractor going to build this? Can they get between the steel bars to vibrate the concrete? If not, all your calculations are useless because the structure cannot perform as designed. An excellent learning tool is working with a contractor for a day or two. You'll quickly learn what does and doesn't work.

Column sizing

- Check beam steel and relative sizes. Remember strong column, weak beam theory.
- Exterior columns usually are 520mm or greater, particularly with taller buildings and close to the sea.
- The core area of a column should not be less than 2/3 of the total cross-section area (i.e. $A_g/A_c \leq 1.5$)

Detailing and analysis

- There is no such thing as a pin detail in reinforced concrete
- The results of an elastic stress analysis probably don't reflect the distribution of internal forces in a concrete element

Durability

- Concrete and aluminium don't mix – the alkaline environment of concrete corrodes the aluminium, which expands and breaks the concrete.
- Ensure that the concrete cover and strength are suitable for the environment. Check with the tables in NZS 3101.

Slabs and foundations

- Don't try to install mechanical anchors closer than 100mm to the edge of the concrete. There's usually a longitudinal bar there.
- Where shrinkage is important, make sure local concrete shrinkage attributes are taken into account in the design and specify the concrete correctly
- Heat buildup requires consideration when large volume concrete pours are undertaken. It is especially relevant when the pour is over 1m thick.
- Specify the correct proprietary shear key hardware. Detail out excess restraint at internal corners

Concrete panels

- Check for ductile failure.
- The precaster will likely make panels from 40MPa concrete, even if you specify lower strength. Take that into account with calculations.

Reinforcement

- Try to use a single grade of the same size bar. For example, avoid using D12 and HD12 on the same site as confusing the two is easy. When specifying domestic work, the contractor will most likely order and install HD regardless.
- Bend diameters for Grade 500E reinforcement are likely to be limited by concrete crushing, not the simple tabulated limits in NZS 3101
- Reinforcement doesn't prevent cracks; it only controls the width of cracks
- Draw your details with the actual bar diameter across the deformations: typically nominal plus 10% - this means that a 32mm bar becomes 35mm.
- The design must allow concrete to go in and allow contractors to use a placement hose where needed (e.g. down columns and walls) and allow air to escape. If in doubt, call a contractor your company has worked with to determine if it's buildable.
- Draw the entire holding down bolt detail inside the cage to make sure it can be built (and that it fits)

Retaining walls

- HD12 at 200crs is the most steel that can fit into 20 series walls. Cover and brittle failure govern with higher ratios.
- With cantilever walls, 20 series block will typically go to 2m high with no backslope or surcharge, 25 series to about 2.8m.
- The width of the footing is typically 60-80% of the wall's height if there is no heel. Width may reduce to 40-60% in low seismicity regions. Check soil crushing at the toe.
- The footing depth should be at least 300mm for HD12 and 350mm for HD16, governed by hook development length and cover.

Placing concrete

- Extra water added to fresh concrete for workability will reduce strength and increase shrinkage and cracking potential
- Ensure the design enables the contractors to vibrate the concrete properly. Excess air in concrete due to poor compaction will reduce strength by 5-7% for every extra percentage of entrapped air
- Gaps of at least 85mm are required to fit a concrete vibrator into the cage.
- Curing is critical to prevent cracking. Concrete is most vulnerable to cracking at early ages, particularly when evaporation exceeds 0.5L/m3 or thermal swings exceed 15 ^{0}C

STEEL

Steel must be of the appropriate grade, and many clients and regulators now require the steel to comply with AS/NZS 5131:2016. Steel Construction New Zealand (SCNZ) has developed a system and template to comply with the Standard. If you're working with steel, membership of SCNZ gives you access to expert advice.

You must protect steel from corrosion. Often a maintenance schedule is needed to comply with the specified design life. Make sure you read through the B2 Practice Advisory put out by Engineering New Zealand (downloadable from the practice Notes and Guidelines page).

Design engineers have long thought the weight of the steel governs the cost of a steel structure. In fact, the cost of requests for information from the fabricator and the labour involved in the fabrication governs anything above a simple beam. Is your design easy to manufacture as well as being compliant? Most good manufacturers will give you feedback on a draft design if you send it to them as it makes their life easier to have good drawings.

General considerations

- Fillet welds with no joint preparation are the cheapest. Speed of welding, including all phases of preparation, is faster than for butt welds.
- Double-sided welds produce less distortion. You can balance weld shrinkage during cooling by using back to back welds.
- For butt welds, a double-sided vee requires less grinding and filler metal than a full penetration vee from one side only. They are therefore faster and cheaper.
- Fillet welds are inferior to butt welds from the stress distribution point of view. The stress path is not a direct one, and this gives rise to stress concentrations in the weld metal and heat-affected zone.
- Fillet welds are inferior to butt welds from a fatigue standpoint. The typical notch effect at the root of a fillet can lead to brittle fracture from cyclic fatigue.
- Where stresses are low, intermittent welds reduce cost and produce less distortion but can lead to gaps in coatings for corrosion protection.
- Design for the thinner member. The joint need only be as strong as the weakest part.
- You're best to weld joints between plates of similar thickness. It helps with heat distribution (i.e., avoids burning the thinner plate) and reduces stress concentrations.
- Consider fatigue – try to avoid abrupt changes of section and stress concentrations.
- Consider access – if a welder cannot see or reach a joint, they cannot weld it!

Beams

- You need to confirm that assumed lateral-torsional buckling restraints can carry the required forces to the ground – don't just assume these are sufficient
- Steel beams are typically 50% of the depth of an equivalent hyspan or 45% for SG8 due to the increased stiffness.

Columns

- Ensure that all columns have lateral restraint provided in two orthogonal directions at the top and bottom.
- Don’t forget to allow for “simple construction” loads per NZS3404 – these are tolerances in the way the load is applied to the columns and results in moments in the columns.

Portals

- Domestic portal size is typically span/20. Deflection often governs – refer to the Engineering New Zealand guidance note (2021)
- Sizing of single-span portals for warehouses is typically span/60-70.
- When designing a portal, you must restrain it against buckling. It is particularly true for industrial buildings. Designers often forget to brace the portal column, make sure you do so.
- You should not use diagonal stiffeners at the knee; you should always specify rectilinear stiffeners. Dr Charles Clifton (amongst others) has written papers on the subject.
- SCNZ has published papers on warehouse portal design – their 2010 paper is useful **https://www.scnz.org/wp-content/uploads/2020/12/GEN7001.pdf**

TIMBER

The most commonly used timber in New Zealand is Pinus Radiata. Engineered timber products are becoming more common for purposes such as framing, it is typically straighter and stronger than standard cut lengths. You cannot use some types of engineered timber externally. You must ensure that timber products for exterior use have adequate treatment.

Buy and read Andy Buchanan's book "Timber Design Guide". The Timber Design Society has copies, and they also have webinars available on timber design.

Beams and joists

- Joist spacing generally requires a maximum of 450mm for domestic situations due to timber flooring's capacity.
- Due to jacking loads, car decks and garages typically need a closer joist spacing (300mm). Check the loadings standard.
- If you're designing beams near a bathroom, check which way the services will run. Plumbers can cut large holes in beams for pipes.
- Deflection typically governs joist and beam size (floor vibration, ceiling sagging). If depth is critical, use an engineered timber product for increased stiffness or a steel beam.

Posts

- Tradespeople frequently cut holes in studs without considering the implications of capacity reduction. If a triple stud is required to support the load, consider a steel post. It indicates that it is critical to the structure, and they can't easily cut through it.

Retaining Walls

- Space poles at about 1m apart, then wall height/10 = pole diameter and wall height = pile depth
- Typically use round poles for walls over 1m high
- Check the strength of the waling planks. Double planking is generally required for walls over 2m.

TYPICAL SPAN TABLE

These values are for simply supported beams only and serve as an indicator for sizing. It's a check against a spreadsheet or computer program and allows you to quickly work onsite with a contractor to get some approximate sizes which you can confirm when you get back to the office.

Vertical loading only

Steel truss	Span/12
Steel roof beam	Span/25-30
Steel floor joist	Span/20
HySpan	Span/15
SG8	Span/12