DESIGN RIGHT

Understanding loads

ENQUIRIES TO THE BRANZ HELPLINE SHOW THAT THE MEANINGS OF CHARACTERISTIC STRENGTH, CAPACITY, ULTIMATE LOAD AND SERVICEABILITY LOAD ARE NOT WELL UNDERSTOOD. WE TAKE A LOOK AT WHAT THE VARIOUS TERMS MEAN.

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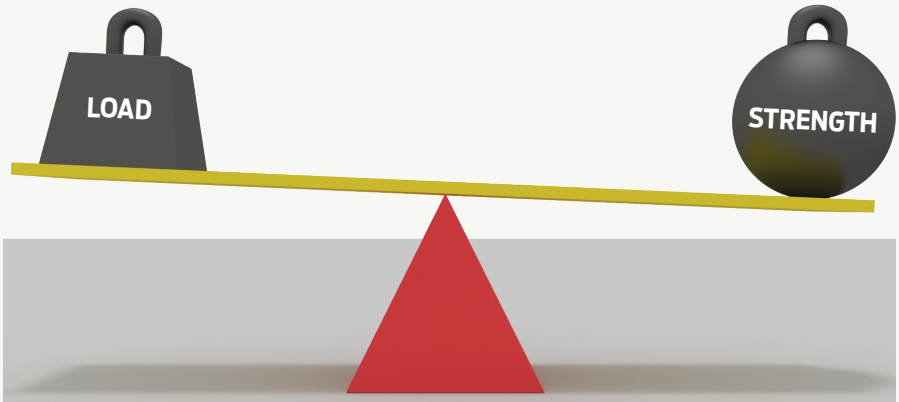

Figure 1 **The strength of the structure should be greater than the applied loads.**

A BUILDING'S STRUCTURE is there for only one purpose – to resist the applied loads on the building with a reasonable margin. The structural designer's role is to size members and design connections so that the strength of the structure is greater than the applied loads (see Figure 1).

Types of loads

Loads could be gravity effects (often called imposed loads), wind or earthquake action among others. *Strength* is the resistance of the structural members to the loads.

NZS 3604:2011 *Timber-framed buildings* refers to bracing loads on the building as *demand*, and to the bracing or fixing strength as *capacity*. So in the NZS 3604:2011 context, it's merely a case of ensuring that the capacity of the fixing – nail, strap, bracket or bracing element – is greater than the demand (see Table 1).

Problem factors

However, in the specific engineering design (SED) context, slightly different terminology is needed to cope with a couple of problems:

- Load – we don't know with certainty how many people will congregate on the floor or how hard the wind will blow or how big the earthquake will be over the life of the building.
- Strength – because of material and workmanship variability, we can't predict exactly how strong a structural member or joint will be.

To make a level playing field for designers and to reduce this uncertainty, the New Zealand Building Code lays down the ground rules in clause B1 *Structure*, and the various New Zealand standards fill in the details (see Table 1).

Table 1

TERMINOLOGY USED IN DIFFERENT STANDARDS

SOURCE	APPLIED LOAD	CALCULATED OR TESTED STRENGTH	DESIGN STRENGTH
NZS 3604:2011	Bracing demand – wind and earthquake. Floor load.	Characteristic strength of connector.	Bracing rating. Connector capacity.
Loading standards (AS/NZS 1170 series)	Imposed load. Earthquake or wind actions.		
Materials standards (NZS 3603:1993)		Characteristic strength of material. Nominal strength of member or joint.	Design strength or capacity.

Rare and frequent loads considered

Based on lots of statistical studies over many years, it is well established that over the life of the structure, smaller loads occur more frequently than larger ones. The Building Code and standards around the world deal with this by requiring structural designers to consider two limit states:

- Ultimate limit state (ULS) – the structure must resist a relatively rare load without failure (it may be damaged but should not collapse). For wind and earthquakes on typical buildings, that rare load is the one expected to occur on average only once in 500 years.
- Serviceability limit state (SLS) – the structure must resist a more frequently occurring load without deforming or deflecting to an extent that may affect its serviceability or amenity.

Verifying strength

The strength of a structure is normally verified by either design calculations or testing.

Verification by design is based on material strengths set by the relevant material standards (concrete, timber and steel), and engineering calculation. This process gives the *nominal* strength of the structure.

Verification by testing involves testing a number of replicate members or components to failure. Because of the variability mentioned already there will be a range of results that looks something like Figure 2, and the problem is to choose a suitable representative strength value. The *characteristic* strength for structural design is set at the value that 95% of the test results will exceed (see Figure 2).

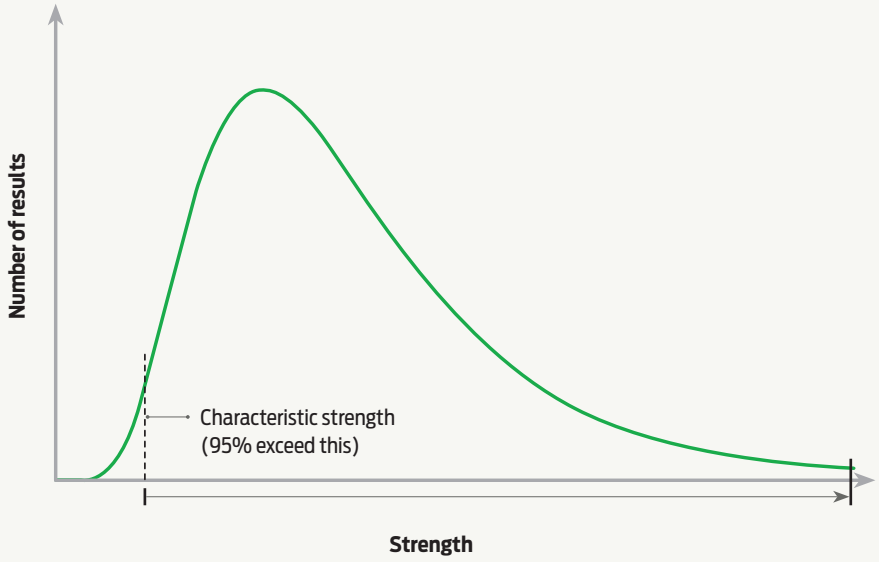

Figure 2 **95% of test results will exceed the characteristic strength.**

To allow for site effects such as workmanship, the nominal or characteristic strength is multiplied by a reduction factor set by the material standard to give the *design* strength. This design strength is then balanced against the applied loads (see Figure 1).

So if you have a component whose strength is given as characteristic strength, the manufacturer or supplier needs to advise what its capacity is. Guidance on this is given in NZS 3604:2011 clause 2.4.7.