IMPLICATIONS OF SCREW DIAMETER ON TIMBER DESIGN

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1 SCREW CONNECTIONS IN ENGINEERED TIMBER STRUCTURES

How often have you been asked recently to specify an alternative to the connection that you have just designed for your engineered timber project?

Did you get asked to change a self-tapping screw or engineered wood screw and substitute it with a gauge screw of similar or greater diameter than specified? These types of requests are becoming more common for timber design engineers and it is important to understand the differences between screws to better understand when and if substitutions are possible.

Most likely, when designing with mass timber (e.g. CLT, Glulam and LVL) and specifying self-tapping or Engineered Wood Screws (EWS) with a diameter larger than 10mm, you would have been asked to substitute it with a coach screw of the same diameter. Or your 6 mm diameter self-tapping screw has been replaced with a traditional 14g wood screw. Why? Because the builder probably could not source the screw from their usual local merchant. But while the self-tapping screw certainly exists, nor everyone is aware of these products, which have had a big influence and impact on the way modern timber structures are designed.

Over the past three years we have experienced a significant uptake in mass timber and prefabricated light timber frame buildings. Screws have become an irreplaceable connector for these designs.

This article is the first of a series in the TDS Journal to provide information about the various types of screws we are currently designing with using NZS 3603:1993 and will be designing with under NZS AS 1720.1, once it is published.

2 TYPES OF SCREWS FOR TIMBER CONSTRUCTION

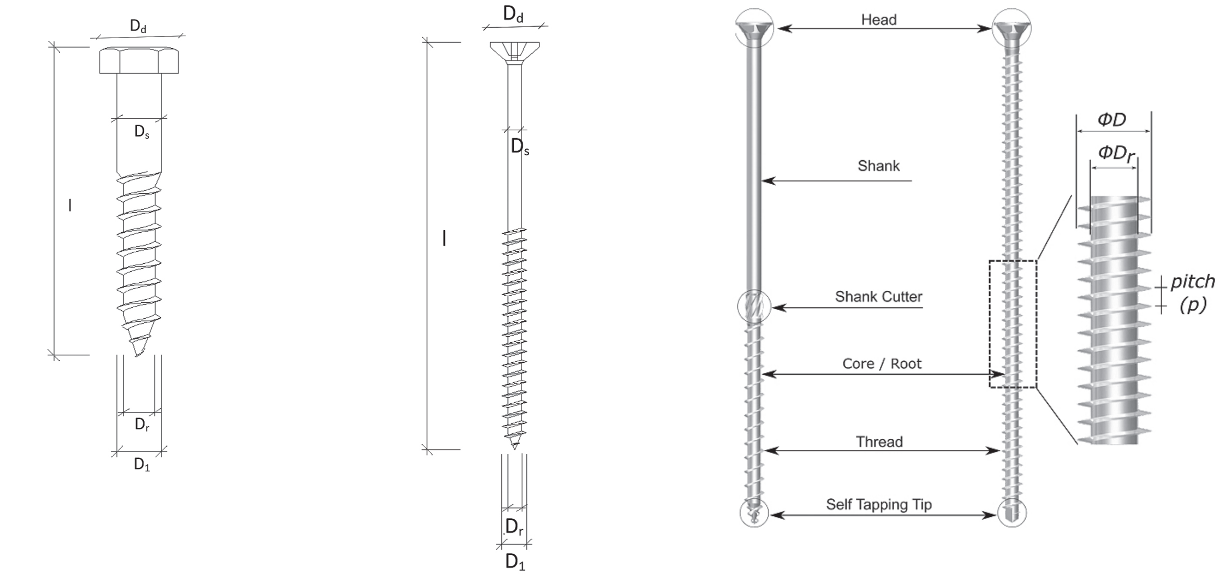
It is important to understand what type of screws we have access to in New Zealand and how the diameter affects engineering designs. The figure below provides a non-exhaustive list of common screw types used in timber construction. Refer also to the glossary at the end of this note.

The screw tip (e.g. normal tip, Type 17 self-drilling tip and proprietary self-drilling tips) and the head of the screw (e.g. cylindrical, countersunk, washer head and special head for steel plates) depend on the purpose of use and manufacturer. Screws are also available in various lengths, coatings, materials and partially or fully threaded.

One of the common misunderstandings when specifying and designing screws, however, is the correct application of the screw diameter. Over the length of the screw, we differentiate four diameters – head (D_d), shank/shaft (D_s), core/root (D_r) and outer thread (D_1) – each of these are required in the verification of different design scenarios.

Coach screws according to AS/NZS 1393 or hex head wood screws according to DIN 571 consist of a metric thread, cut into the shaft of a raw carbon steel dowel. The resulting shank and the outer thread diameter

DIN 571 Hex Head Wood Screw / AS/NZS 1393 Coach screw	NZ Gauge screw / Bugle-head screw	Self tapping or Engineered Wood Screw (EWS)- – partial thread / full thread (photo adapted from MTC Solutions (2020))



diameter nomenclature as suggested in NZS AS 1720.1 DRAFT

are the same, hence the reason to use $D_1 = D_s$ as the design diameter in most applications.

Gauge screws as well as self-tapping screws or engineered wood screws (EWS) are manufactured from a carbon steel wire. The thread is created by rolling the wire through two pressing jaws and can extend from a full thread to a partial thread. During this rolling process the diameter of the shank is reduced to the core or root diameter (D_r). The differences between gauge screws and EWS is in the material, diameter, manufacturing process and quality assurance including testing.

The commonly used “gauge” or “bugle-head” screws do not have a manufacturing standard, but are referred to in NZS 3603 as wood screws with a certain shank diameter D_s defined by the gauge number. Thirty years ago, when NZS 3603 was written, these gauge screws were tested, and their shear capacities tabulated. However, screw geometries have changed since then, and manufacturers now commonly refer to the outer thread diameter when they sell their screws, rather than the shank diameter as required by the standard. Therefore, builders now commonly use screws which have a smaller shaft diameter when compared to the one specified. It is therefore recommended to specify the shank diameter rather than referring to a gauge number when specifying gauge screws, and to follow up with the builder to ensure the correct screws are installed. Long term, it would be ideal to have a manufacturing and specification standard comparable to other countries, to ensure that the screws have the appropriate geometry and provide the required performance.

On the other hand, for EWS the shear capacity is determined using the European Yield Method (EYM) and the yield moment of the screw (M_{yk}) according to supplier specific tested design parameters, documented in the screw specific European Technical Approval (ETA) or in the Declaration of Performance (DoP). These documents also define minimum screw edge and end distances, which can vary greatly between suppliers. Note that for EWS typically the outer thread diameter D_1 is used to describe the screw and to determine capacities, which is different than for gauge screws which refers to the shank diameter, D_s.

For all above mentioned screw types, the withdrawal strength in timber is based on the embedment of the thread in the timber defined via the withdrawal parameter ($f_{ax,k}$), which is defined in ETAs for EWS and in Table 4.7 of NZS 3603 for gauge screws. Also the minimum tensile capacity of the screws needs to be checked, which is based on the root diameter D_r.

Both the current NZS 3603 and the draft for public comment version of NZS AS 1720.1 provide tabulated capacity values for coach screws and gauge screws. EWS however will require the specific design to the ETAs or DoP, combined with the procedure outlined in the detailed method that was introduced in the draft for public comment version of NZS AS 1720.1.

It is worth noting that when designing EWS one cannot use the tabulated values from NZS 3603 or NZS AS 1720.1, but needs to follow the guidance from the ETAs. Thus, none of these EWS can be substituted in design or construction with gauge screws, coach screws or EWS from other manufacturers, without reverifying it with the correct design method and respective design parameters.

3 THINGS TO CONSIDER WHEN SPECIFYING SCREWS

From BRANZ Guideline February 2012 – Screw Gauges - "Engineers who are specifying screw gauges for structural applications need to be aware of shank diameter differences that occur for a given gauge. For example, for a 10-gauge screw shank, the diameter can range from 2.74 mm to 5.12 mm. The former would only equate to a 4-gauge screw using Table 4.5 in NZS 3603:1993 Timber structures standard, which requires a 10-gauge screw to have a minimum shank size of 4.88 mm. **We suggest that, when specifying, it would be safer to state the minimum shank diameter rather than specifying the gauge."**

This discrepancy in screw diameters has also been highlighted as a potential issue by John Tait in the SESOC Journal, Vol 33, No 2, September 2020.

This problem typically does not occur with EWS, as both the product and the design values always refer to the outer thread diameter D_1.

Another major difference between gauge screws produced for New Zealand and EWS are the material properties and the Quality Assurance (QA) process during manufacturing. EWS are produced from drawn carbon steel and afterwards undergo heat treatment (annealing) in order to relieve internal stresses that occur whilst forcing the thread onto the shank. ETAs also require the screws to undergo testing as part of a strict QA procedure to ensure the screws can bend without breaking in order to guarantee minimum performance.

The majority of gauge screws available in NZ however are produced from 1020 carbon steel, that is already brittle before any cold forming, which further compromises most of its yield behaviour under load. Furthermore, most of the readily available gauge screws off the shelf do not undergo a controlled heating process following forming to relieve internal stresses nor undergo a stringent QA process to ensure consistent strength and ductility.

Although subject to engineering judgement, it is recommended to only use gauge screws as per NZS3603 for static loading, as ductile behaviour cannot be guaranteed. Further, when designing engineered wood structures, joints critical for the lateral load resisting system load path and gravity connections of principal structural members should ideally be designed with EWS, following the design values from the ETA-approval or Declaration of Performance (DoP). Gauge screws can still be used, but the design engineer needs to ensure that the correct screw with the specified shank diameter is used on site.

GLOSSARY

Self-tapping Screws or Engineered Wood Screws = screws manufactured based on EN 14592 or a European Technical Approval (ETA) with material properties specified in a Declaration of Performance (DoP) document.

Gauge Screws or Bugle-Head Screws = wood screws to NZS 3603 or NZS AS 1720.1. The gauge number refers to the shank diameter of the screw.

Hex Head Wood Screws or Coach Screws = heavy duty screw which has a square or hexagonal head and a cut externally threaded mild steel shaft to DIN 571 or AS/NZS 1393

Outer Thread or Thread Diameter D_1 = outer diameter of the thread part of the screw

Shank or Shaft Diameter D_s = diameter of the non-threaded part of the screw shank

Core or Root Diameter D_r = inner diameter of the thread part of the screw

Head Diameter D_d = diameter of the screw head

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