Growth in Light Gauge Steel

Use of cold-formed light gauge steel is a growth area in Australia. Our country arguably leads the world in the development and manufacturing of leading-edge, cost-effective, high-performance roofing and walling systems. Application in areas such as domestic framing systems is gaining traction and newer application areas such as for modular construction and primary structural framing in mid-rise buildings are taking advantage of steel's strength, stiffness, robustness, dimensional stability and environmental resistance. The supply chain for cold-formed light gauge steel is well developed and design Standards exist to provide designers with specifications for cold-formed steel structural members for load-carrying purposes.

Steel and the Shift to Medium-Density Living

The increasing urbanisation of our large cities is forcing a shift in housing to higher-density apartments, in both greenfield and brownfield locations. Taking advantage of the benefits of steel, there are now significant developments providing a range of possible steel solutions for mid-rise construction.

In particular, cold-formed steel products and systems can improve the construction process through the provision of a material with improved strength-to-weight ratio, portability, offsite manufacturability, recyclability, and termite and mould resistance.

Importance of Light Gauge Steel

Cold-formed light gauge steel has been utilised as the primary load-bearing structure in mid-rise construction in a number of countries in recent years. Systems are often proprietary and solutions bespoke, but moving towards a level of acceptance that may see increasing use in the near future.

The scenario is similar in Australia, with some developments already complete and a range of research activities underway to establish not only the technical foundation for these high-performance solutions, but also the ecosystem of industry support necessary to ensure solutions are readily available to service increasing demand.

Image courtesy of BlueScope.

Technical Solutions Research

Research on a range of technical solutions is currently underway or has recently been completed to support the expanding use of cold-formed light gauge steel. The research has incorporated the following areas:

- Revised design Standard: AS/NZS 4600 *Cold-formed steel structures* was recently revised to incorporate higher-performance analysis methodology and to better address fire engineering requirements.
- Research on fire engineering: research by Professor Mahen Mahendran at the Queensland University of Technology helped establish the new fire provisions included in AS/NZS 4600
- Research undertaken within the Steel Research Hub at the University of Wollongong on innovative solutions for cold-formed steel intensive mid-rise buildings

New Standard a Quantum Leap Forward

The steel used to construct everything from prefabricated framework and facades, through to lighting poles and fences is the focus of a newly published Standard, backed by the latest Australian research and technology. AS/NZS 4600:2018 - *Cold-formed steel structures* was published in May 2018, following extensive consultation with stakeholders across Australia and New Zealand. The new edition has substantial changes compared with the 2005 edition, endowing it with the potential to be a primary reference in the National Construction Code 2019.

“This new Standard is a quantum leap forward for the steel industry,” said Professor Greg Hancock, Chair of the Standards Australia Technical Committee responsible for the Standard. “This is a world leading Standard that places Australia at the top of the list in terms of the most innovative steel consumers.”

The type of steel covered by AS/NZS 4600:2018—often referred to as light gauge steel—is everywhere. It is in high demand in the construction sector, delivering safety and durability, strength and flexibility.

Today, mid-rise construction and modular construction are beginning to use cold-formed steel in major structural elements. In fact, light gauge steel is now so light and so strong that it can be used in impressively long spans, effectively negating the necessity for load bearing walls.

Not surprisingly, prefabricated modular construction and light gauge steel work well together with the light gauge steel often used in prefabricated frameworks and facades. Light gauge steel frameworks are particularly useful in constrained construction sites, offering compressed erection times compared to traditional construction methods.

Changes to AS/NZS 4600

The Direct Strength Method (DSM) of design has undergone substantial research since the 2005 edition of AS/NZS 4600 was published; this research now features heavily in the revised *Section 7 - Direct Strength Method (DSM) of Design*. Section 7 now covers sections with holes and inelastic reserve capacity, shear and combined actions, and a wider range of pre-qualified sections, including most sections with longitudinal web and flange stiffeners (based in part on Australian research at the University of Sydney on high strength sections with multiple stiffeners).

Section 8 - Testing has been updated to align with the National Construction Code, which recently underwent changes related to the loading data for wind, snow and earthquake from 50 year to annual probability of occurrence. According to Hancock, “Two significant changes have been made to *Section 8* in the new edition. They are the determination of design values based on prototype testing where the average of the test results can now be used, and calibration of a strength prediction model based on prototype testing.”

New sections have also been added to the revised version of the Standard, including *Section 9 – Fire*, which outlines design requirements for fire protected members at elevated temperatures. “Based on research undertaken at the Queensland University of Technology, the methodology in *Section 9* has been developed for Australian high strength steels to AS 1397, assuming protected cold-formed steel building members,” said Hancock.

Other new sections include *Appendix B - Methods of Structural Analysis* (which includes first order, second order and advanced structural analysis based on research at the University of Sydney), and *Appendix D - Buckling Stresses*. *Appendix D* now includes requirements for all elastic buckling solutions for local, distortional and flexural-torsional modes to simplify design compared with the previous 2005 edition of AS/NZS 4600 where the buckling equations were scattered through the Standard and difficult to follow.

Finally, *Section 5.3 - Power Actuated Fasteners (PAFs)* now includes requirements for PAFs in tension and shear, and a revised *Section 5 - Connections* includes new requirements for block shear rupture and net section tension, and for screw connections under combined shear and tension.

“Significant research has been performed recently at the University of Wollongong on net section fracture and block shear rupture. New equations have been developed and included in *Section 5 - Connections* for net section fracture and block shear rupture where new shear lag factors have been incorporated. Further, the shear planes in block shear rupture are now based on average shear planes rather than gross or net sections at bolted connections,” said Hancock.

Direct Strength Method of Design and THIN-WALL-2

Two basic design methods for cold-formed steel members are available in AS/NZS 4600:2018. These are the traditional Effective Width Method (EWM) specified in *Section 2 - Elements* and *Section 3 – Members*, and the newly developed Direct Strength Method of design (DSM) as specified in *Section 7*.

The EWM has been ‘grand-fathered’ in the revised edition on the basis that Committee BD/82 of Standards Australia required that all existing design methods are maintained in their current form without restriction.

The Direct Strength Method (DSM) of design is a new method which accounts for the behaviour of complete cold-formed thin-walled sections including longitudinal stiffeners rolled into the sections. It relies on the ability to compute the buckling stresses of thin-walled sections.

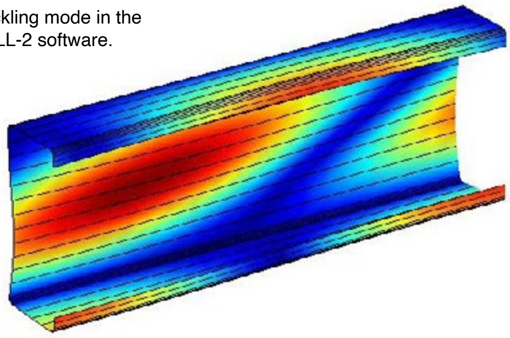
With the inclusion of shear design in the DSM, new Finite Strip Method (FSM) software has also been developed at

Architectural rendering of a seven-storey cold-formed light gauge steel apartment building. Image courtesy of Steel Research Hub, University of Wollongong.

the University of Sydney. Called THIN-WALL-2, this software allows easy DSM design for compression, bending and shear using a MATLAB graphical interface and Visual Studio C++ computational engines.

The THIN-WALL-2 program is written to define input data using a Graphic User Interface (GUI) to perform pre-buckling and buckling analyses of thin-walled sections under generalised loading. The loading may contain uniform loading and localised loading. The GUI is then used to display the results of the analyses.

Shear buckling mode in the THIN-WALL-2 software.



It is also possible to use the program to perform a cross-section analysis to generate the section properties. The cross-sections can be formed from different shapes, including open and closed sections or mixed sections.

Innovative Solutions for Cold-Formed Steel Intensive Mid-Rise Buildings

A multidisciplinary research group within the Steel Research Hub (based at the University of Wollongong) is aiming to develop new products and systems for cold-formed, steel-intensive mid-rise buildings. Mid-rise residential buildings are usually between four to eight storeys in height. Designing and constructing such buildings using primarily cold-formed steel products poses several structural challenges.

Under the leadership of Professor Lip Teh at the University of Wollongong, research undertaken by Dr Aziz Ahmed and Refat Bhuiyan is focused on the following issues.

Firstly, there is a lack of cold-formed steel-based shear walls to withstand high wind loads that may be experienced by the mid-rise buildings. Secondly, the lateral load resisting system of such buildings are currently designed without accounting for the advantageous effect of gravity load bearing walls, due to the lack of a system behaviour modelling technique suitable for practicing engineers. Thirdly, there are critical gaps in the current simulation capability of load-displacement and failure behaviour of shear bolted and screwed connections in steel-intensive construction. Finally, there are inadequate design guidelines for various components in a cold-formed steel building structure.

The Steel Research Hub research team successfully developed and tested high-capacity strap-braced shear panels that are optimised for Australian conditions. Although experimental tests and further development are ongoing to improve the ductility of the shear panels, the test program has already developed shear panels each with a capacity far greater than that of cold-formed steel shear panels typically used in Australia.

Another research outcome by the team is the formulation of an efficient modelling technique to simulate the system behaviour of cold-formed steel intensive mid-rise buildings. It is anticipated that this technique will assist practicing engineers to optimise the design of lateral resisting systems for such buildings.

The team has also developed an advanced numerical technique to simulate the complete response of shear bolted and screwed connections between cold-formed steel components. This enables a more accurate determination of not only the ultimate capacity, but also the displacement under a particular load. This leads to improved understanding of connection behaviour, and facilitates the formulations of structural design equations and analysis procedures for cold-formed steel structures.

Within these projects, several other experimental activities have been completed, including the testing of untightened double-shear bolted connections, nail connections, angle clip connections and shear fracture specimens. Design formulations and guidelines based on these test results will fill some of the existing gaps in the design of cold-formed steel structures. The findings will also inform future developments of new cold-formed steel products for mid-rise residential construction.

Development of Prototype Steel Intensive Mid-Rise Building Designs

As part of the multi-disciplinary Steel Research Hub team, Alberto Escribano and Dr Tillmann Böhme (Faculty of Business, University of Wollongong) investigated supply chain aspects of pre-fabricated, load-bearing cold-formed steel for mid-rise apartment construction.

Interestingly, Dr Böhme's academic career is based on the adoption of the systems concept best known as the Toyota Production system to alternative industries such as engineering to order, healthcare, or in this case, to construction.

"The project team applied a supply chain diagnostic approach to our research to better understand the dynamics in the current Australian construction industry and to obtain field insights on a potential cold-formed steel construction adoption pathway," Dr Böhme said.

A considerable amount of time was spent with the Steel Research Hub partner companies, BlueScope, Cox Architecture and Stockland, and external construction companies, to understand and document current practices and review recently completed reinforced concrete construction projects.

Interestingly, the team found that on average, 1,122 inducted people worked on-site during 55 weeks of construction time for the nine investigated concrete mid-rise apartment developments. The mean construction completion delay was eight weeks, and the mean time overrun on programmed activities was 195 days. However, not all time overrun activities were part of the critical path, hence the reduced impact on overall construction time. Two of the nine projects achieved overall on-time completion, but only because the project managers recovered earlier delays during the services and finishes phases.

For the analysed projects, more than 60 percent of the total project delays occurred during the substructure and superstructure phases; in particular the formwork installation due to materials supply issues and inclement weather during concrete pouring. Hence, the phases with the largest contribution to productivity loss in concrete construction are substructure and superstructure, resulting in further productivity losses in the fit-out phase due to the efforts of time compression.

The project used this baseline data to investigate the impact that the use of a load-bearing cold-formed steel structure alternative would have on a mid-rise apartment construction project. Due to the absence of existing cold-formed steel mid-rise construction projects in Australia, the team had to use field insights from relevant overseas projects. They contextualised the data for regional application by incorporating data from the local steel industry, fabrication times and cost, installation capacities, and transport restrictions.

The simulated outcomes showed a considerable decrease in cost as well as time saving, due to higher amounts of off-site manufacturing activities. The simulation identified further barriers to productivity improvements in the Australian construction industry, as a fully integrated construction management system was not available.

The team had to modify an existing 3D construction file of the building to make it relevant for supply chain and project coordination. Additional software packages were sourced to take the 3D model to 4D (time) and 5D (cost) to complete the comparison.

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