Innovation in Steel Framing

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ABSTRACT
The lack of uptake in steel framing in the housing sector is partly due to (i) the lack of generic 'span tables' that enable rapid preliminary designs and estimates and (ii) the difficulties for building surveyors and inspectors in approving and inspecting steel framing. This paper describes some recent developments that may alleviate these problems to some extent. The ABCB has recently introduced a 'Protocol for structural Software' that will enable submissions generated by software to be accepted without being 'signed off' by a professional engineer. The National Association of Steel-framed Housing (NASH) has been working to produce a set of generic 'span tables' which will be published as the NASH Standard - Residential and Low-rise Steel Framing – Part 2. Span tables are generated for a number of standard conditions such as types of roof (sheet or tile), spacings and spans. At present, the Standard is intended to cover wind classification N1 to N4 for the design and detailing (including connections) of: (a) steel stumps, (b) floor joists and bearers, (c) single and double storey wall systems including posts, (d) roof beams, rafters, roof and ceiling battens and (e) bracing systems.

KEYWORDS
Cold-formed; Framing; Housing; Innovation; Steel; Structural;

INTRODUCTION

Innovations in light steel were stimulated with the development of low cost programmable roll formers for high strength coated steel and design software for personal computers. Light-gauge high tensile steel sheet is capable of being cold-formed into a variety of shapes. This enables manufacturers to develop a wide range of efficient sections. Each housing system adopts a number of section shapes suitable for its unique design. These section shapes are owned by the particular manufacturer, many of whom do not publish comprehensive load tables for their products. Thus, the ease of fabrication encourages innovative design but makes it difficult for designers and builders to specify and construct using multiple components and systems. In addition, building surveyors and inspectors have had trouble in inspecting and approving steel framing as they do not always have access to the proprietary design specification. The lack of uptake in steel framing is partly due to these reasons. Two recent developments have alleviated these problems to some extent. One is the regulatory requirement that allows individual designs generated by computer software to be accepted without being 'signed off' by a professional engineer provide that the software has been certified as in compliance with the ABCB 'Protocol for Structural Software' (ABCB, 2011). The other is the development of standardized generic span tables and building practices by the National

Association of Steel-framed Housing (NASH). This paper discusses these developments in some detail.

ABCB PROTOCOL FOR STRUCTURAL SOFTWARE

The assessment and approval of proprietary prefabricated structural systems has been a matter of considerable discussion. These systems essentially use a software package to produce a design solution for a specific proposal. There is a high degree of reliance on the software to produce product specifications that are in compliance with the regulatory requirements of the Building Code of Australia (BCA). Professional engineers have used structural software for many years as part of the design process and the outcomes remain the responsibility of the engineers. However, software development has reached the stage that a person who is not an engineer can use it to produce a design and submit it for regulatory approval. The Protocol is designed to assist with the approval process when the submission is produced by the software without engineering supervision. The responsibility in this case rests with the software providers in relation to the content of the software and with the users for their correct usage.

The Protocol describes the essential elements of structural software such as input and output characteristics, documentation, testing, quality assurance and user training. These are general characteristics of a good software package. The Protocol is applicable to software that uses criteria derived from BCA Deemed-to-Satisfy provisions and its referenced documents and at present, limited to steel and timber trussed roof systems and framed building systems within the geometrical limits of AS 4055 (Standards Australia, 2006) i.e. houses.

To demonstrate compliance of the software with the Protocol, a Compliance Document must be prepared by the software provider and appraised by an independent assessor. The assessor is to provide a summary of the Compliance Document to be included with any submission for certification.

When poor outcomes occur, it is generally recognised that the software itself is usually not the problem. Incorrect or inappropriate use of the software, including inadequate communication to the users and other trades on what needs to be done, often resulting from inadequate training have been found to be the sources of most problems encountered in practice. The assessor has to inspect these associated documents such as software manual and installation manual as well. In addition, the Protocol includes suggested checklists for the software user and construction supervisor addressing these issues.

Some steel frame software developers used the Protocol before it was incorporated in regulation. They found the Protocol helpful in the refinement of their software package and associated documentation.

NASH STANDARDIZED GENERIC SPAN TABLES AND BUILDING PRACTICES

Design principles

The NASH generic span tables are generated based on the NASH Standard ‘Residential and Low-rise Steel Framing Part 1: Design Criteria’ (NASH, 2005) – a BCA referenced document. Supplementary information is drawn from the NASH Handbook ‘Design of Residential and Low-rise Steel Framing’ (NASH, 2009) for non regulated issues. Wind is the dominant environmental load and the wind classification is in accordance with AS 4055. Buildings other than housing may be designed using the equivalent design wind velocity calculated according to AS/NZS 1170.2. (Standards Australia, 2011).

Standardized components

Light steel components cannot be standardized by their section geometry because manufacturers have chosen to optimise their design by using a wide variety of shapes. The components have therefore been standardized by their relevant minimum structural properties and nominal functional dimensions, with examples of commercially available components. The specified properties vary with the type of component. For example, generic studs are specified in terms of stud height, axial and bending capacities. The capacities can be established by calculation or testing in accordance with the NASH Standard - Part 1. Based on these properties, span tables are generated for a number of standard conditions such as type of roof (sheet or tile), spacing and span. For other components which industry has opted to use, the same type of section can be standardized by section geometry as is usual practice.

Table 1. Standardized components and their specified structural properties.

Component	Typical sections	Standardized properties
Roof		
Roof battens	Top Hats	Second moment of area, section modulus, torsion & warping constants
Roof rafters	C Purlins	Second moment of area, section modulus, torsion & warping constants
	Rectangular Hollow Sections (RHS)	AS/NZS 1163
Roof Beams	C Purlins	Second moment of area, section modulus, torsion & warping constants
	RHS	AS/NZS 1163
Ceiling battens	Top hats	Second moment of area, section modulus, torsion & warping constants
Wall		
Wall studs	Lipped and unlipped C sections	Moment and axial capacities for standard stud heights
Top & bottom plates	Lipped and unlipped C sections	Moment and shear capacities for standard sub heights
Posts	Lipped and unlipped C sections	Stud spacing, moment and shear capacities
	RHS	AS/NZS 1163
Floor and sub-floor		
Steel stumps	RHS	AS/NZS 1163
Floor bearers	C Purlins	Second moment of area, section modulus, torsion & warping constants
	RHS	AS/NZS 1163
Floor joists	C purlins, Top Hats,	Second moment of area, section modulus, torsion & warping constants
	RHS	AS/NZS 1163

Components that are in the process of being standardized are listed in Table 1. Where possible, an appropriate Australian Standard is referenced e.g. AS/NZS 1163 (Standards Australia 2009). However the industry has developed many proprietary sections in order to provide competitive solutions for the market. For instance C purlins are regularly used and specified, but there is no Australian Standard for these sections. A survey of sections available from Australian manufacturers was undertaken and it was found that there were only minor differences and a table of minimum properties (Figure 1 and Table 2) was developed so that span tables can be prepared. Similarly minimum sections properties have been prepared as shown in Figure 2 and Table 3 for 'Top Hat' sections.

However for wall studs, many companies have spent a considerable amount of effort developing economic sections to suit their particular market. The benefit of roll forming studs is that the section can be optimised to give the required capacity by varying base metal thickness (BMT), steel grade, position of stiffeners as well as modifying the depth and flange width of the stud. Also different cities and companies around Australia and New Zealand have adopted different standard stud depths ie 70 mm, 75 mm and 90 mm with different grades of steel ie G2, G300, G450, G500 and G550. Watson et al (2010) investigated this problem and proposed classifying studs by their axial and moment capacities for standard stud heights of 2400 mm, 2700 mm, and 3000 mm. This provides a simple route for engineers, architects, building designers and drafts persons to design and specify the steel frame. It also should assist building surveyors and inspectors in approving and checking the construction. In addition it facilitates modifications to the structure during its life. Consequently it is proposed that the NASH Standard Part 2 will adopt this approach. The proposed classification for studs is given in Table 4. These capacities include an allowance for service holes, and the capacities may change due to industry feedback and further analysis of common studs used in the market.

Lintels remain a difficult component to standardize. Typical industry practice is to treat the lintel as a composite section consisting of the top plate and the additional C or L section used to increase its load carrying capacity. Structural modelling of this sub-assembly is particularly difficult if the resulting section is non symmetric, as the amount of fixings are generally not adequate to ensure complete interaction of the components and the set-up is sensitive to the boundary conditions. Testing of the whole sub-assembly seems to be the only way to establish its load carrying capacity. Other options for lintels include trussed headers, purlins and rectangular hollow sections.

Although there are software packages for roof truss design, span tables for roof trusses can be generated if the truss configuration is standardized and generic properties for top chords, bottom chords and web members are specified in terms of their axial and flexural capacities and slenderness ratios. However for the first edition of Part 2, it is currently not proposed to include trusses.

AS/NZS 4600 requires that the strength of screw is considered as well as the strength of the steel when designing a connection. Issues related to the design of screw connections are covered in more detail in Watson et al (2010). Unfortunately the strength of screws is not adequately covered in AS 3566.1 (Standards Australia 2002). Therefore Table 5 was developed based on experimental data from a number of manufacturers to cover this lack of information.

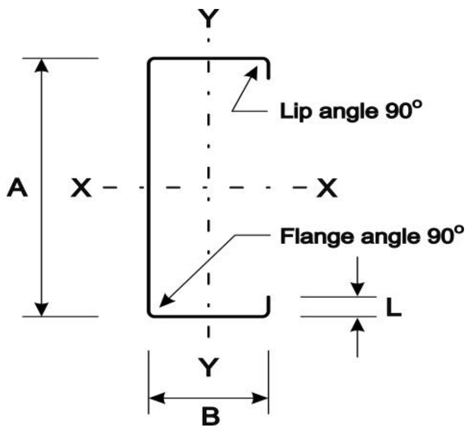

Figure 1. C Section (Purlin)

Table 2. Dimensions and properties of steel C sections (Purlin)

Section Designation	Grade (AS 1397)	Nominal Dimensions			Minimum Section Properties					
		Web depth A	Flange width B	Lip length L	Base metal thick-ness BMT	I_x	$Z_{x\ e}$	I_y	J	I_w
		mm	mm	mm	mm	10^6 mm^4	10^3 mm^3	10^6 mm^4	mm^4	10^9 mm^6
C10010	G550	100	50	13	1.0	0.36	5.30	0.08	70	0.16
C10012	G500	100	50	13	1.2	0.44	6.70	0.09	120	0.19
C10015	G450	100	50	13	1.5	0.54	8.70	0.11	240	0.24
C10019	G450	100	50	13	1.9	0.68	12.0	0.14	490	0.31
C15012	G500	150	64	16	1.2	1.30	11.5	0.19	170	0.84
C15015	G450	150	64	16	1.5	1.60	17.0	0.24	330	1.10
C15019	G450	150	64	16	1.9	2.00	21.0	0.30	670	1.40
C15024	G450	150	64	16	2.4	2.50	30.0	0.39	1360	1.81
C20015	G450	200	75	18	1.5	3.50	24.0	0.40	415	3.06
C20019	G450	200	75	18	1.9	4.50	36.0	0.53	850	4.24
C20024	G450	200	75	18	2.4	5.65	47.0	0.68	1720	5.54
C25019	G450	250	75	20	1.9	7.60	46.0	0.56	970	6.90
C25024	G450	250	75	20	2.4	9.60	64.0	0.72	1960	8.92
C30024	G450	300	100	25	2.4	17.0	90.0	1.50	2420	26.8
C30030	G450	300	100	30	3.0	21.0	120	1.95	4770	35.7
C35030	G450	350	125	30	3.0	35.0	155	3.80	5710	90.0

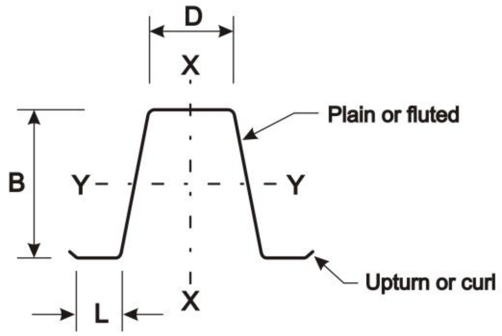

Figure 2. Top Hat section

Table 3. Dimensions and properties of steel top hat sections

Section Designation	Grade (AS 1397)	Nominal Dimensions			Minimum Section Properties					
		Height B	Width Top D	Width Flanges L	Base Metal Thickness BMT	I_x	I_y	Z_{ye}	J	I_w
		mm	mm	mm	mm	10^3 mm^4	10^3 mm^4	10^3 mm^3	mm^4	10^6 mm^6
TH2042	G550	20	30	12	0.42	15.0	3.50	0.22	2.50	0.40
TH4055	G550	40	35	15	0.55	65.0	22.0	0.79	9.00	7.50
TH6075	G550	60	35	20	0.75	115	74.0	2.30	26.0	13.0
TH10075	G550	100	35	20	0.75	150	240	3.50	37.0	60.0
TH10010	G550	100	35	20	1.00	200	320	6.10	90.0	80.0
TH12070	G550	120	40	35	0.70	480	490	7.30	40.0	320
TH12090	G550	120	40	35	0.90	620	630	9.20	87.0	420

Table 4. Stud classification

	Stud capacities					
Stud height	2400 mm		2700 mm		3000 mm	
Stud type	$\varphi_c N_c$(kN)	$\varphi_b M_b$(kNm)	$\varphi_c N_c$(kN)	$\varphi_b M_b$(kNm)	$\varphi_c N_c$(kN)	$\varphi_b M_b$(kNm)
SA	8	0.6	8	0.6	8	0.6
SB	12	0.8	12	0.8	12	0.8
SC	16	1.0	16	1.0	16	1.0

Table 5. Minimum design shear capacity of screws complying with AS 3566.1

Screw Designation/Size (No. - TPI)	10-16	12-14	14-10	14-20
Design shear capacity (V_s) (kN)	4.9	7.2	8.3	8.5

Standardized building practices
NASH also attempts to standardize building practices in areas such as connections and bracings.

Bracings. Wall and subfloor bracings are standardized by providing wind pressures on building surfaces with wind classification, width of building and roof pitch. These tables are different from those given in AS 4055 because there are discrepancies between the formulae and the tables provided in AS 4055. Typical bracing details as well as values for nominal wall braces and structural braces are provided based on test data supplied by industry and research institutions. Roof bracing details for pitched roofs, gable roofs and trussed roofs are also provided.

Connections. Fixings and tie-down details are also provided, including nominal (minimum) and specific fixing requirements. Tables for net uplift wind pressures for tie down requirements are also provided. Capacities for fasteners and common connections will also be provided.

Service holes. Where holes are less in diameter than half the stud depth, rules for minimum spacing of holes are proposed which are based on AS/NZS 4600 (Standards Australia 2006) and research carried out by Clayton (2010) which allows closer spaced holes for holes less than half the depth of the stud. The member capacities given in Table 4 make allowance for service holes.

Other issues
Manufacturing and assembly tolerances. This is a mandatory requirement in NASH Standard Part 1 and ensures that when components are used in conjunction with each other, they will perform structurally in accordance with the assumptions in the Standard.

Durability. This is provided as an informative Appendix at this stage because the issue is still controversial. The design criteria in the NASH Standard Part 1 assume that components will fulfil their structural function for the intended life of the structure. The NASH Handbook provides guidance to assist the designer to develop an appropriate durability solution. The NASH Standard Part 2 refines this guidance and makes it readily accessible to a range of users of the Standard.

Steel components used in residential and similar construction are exposed to widely varying corrosive conditions, including salt and pollution deposition rates, varying ventilation levels, natural surface washing and maintenance regimes. Some of these factors are not well understood outside the research and manufacturer communities, and making that understanding accessible to users is a key objective of the Durability Appendix. The Appendix also encourages suppliers of components and systems to provide durability solutions and advice in a standardized manner. The information format is a table comprising a list of building-specific applications and columns of corrosion classifications based on AS 4312 (Standards Australia 2008). Each table cell contains a group of recommended solutions that is as inclusive as possible of available and practical products, coatings and maintenance practices.

Proprietary systems: Manufacturers can design their proprietary systems in accordance with NASH Standard Part 1 which should be more economical than designs prepared in accordance with the proposed new standard as the manufacturer can optimise their whole solution. Therefore it will quite common for a manufacturer to structurally redesign the framing systems to suit their system and provide the manufacturing data to their roll formers. However it is anticipated that the manufacturer will use the new standard for some components. In addition, on site changes will usually be carried using the new standard as it allows a complying solution to be very quickly designed.

CONCLUSIONS

The paper describes several developments that may facilitate the uptake of steel framing in residential construction. The ABCB Protocol for structural software facilitates the acceptance of computer generated submissions and is, by itself, useful in the development of good software packages. The NASH Standardized Generic Span Tables and Building Practices when completed will be the first of their kind. They should enable architects and building designers to quickly design and specify light steel framing for the housing and similar low-rise buildings.

REFERENCES

ABCB (2011). *Protocol for structural software* Australian Building Codes Board

Clayton, TG (2010). *Design of steel wall studs with service holes* 5th Civil Engineering Conference in the Asian Region and Australasian Structural Engineering Conference 2010, Sydney, N.S.W.: Engineers Australia, 2010

NASH (2005). *NASH Standard 'Residential and Low-rise Steel Framing Part 1: Design Criteria'.* National Association of Steel-framed Housing Inc.

NASH (2009). *NASH Handbook 'Design of Residential and Low-rise Steel Framing'* National Association of Steel-framed Housing Inc.

Standards Australia (2002). *Self-drilling screws for the building and construction industries - General requirements and mechanical properties* AS/NZS 3566.1

Standards Australia (2005). *Cold-formed steel structures* AS/NZS 4600

Standards Australia (2006). *Wind loads for housing* AS 4055 – 2006

Standards Australia (2008). *Atmospheric corrosivity zones in Australia* AS 4312

Standards Australia (2009). *Cold-formed structural steel hollow sections* AS/NZS 1163

Standards Australia (2011). *Structural design actions - Wind actions* AS/NZS 1170.2

Standards Australia (2011a). *Continuous hot-dip metallic coated steel sheet and strip - Coatings of zinc and zinc alloyed with aluminium and magnesium* AS 1397

Watson, KB; Kelly, MH; Pham, L and Gad, EF. (2008). *The Development of Generic Span Tables for Cold Formed Steel Studs in Residential and Low-rise Construction* Australasian Structural Engineering Conference 2008, Melbourne, Australia: pg 1064-1072.

Watson, KB; Pham, L; Kelly, MH and Collinson D. (2010), D. *Shear Strength of Screws* 5th Civil Engineering Conference in the Asian Region and Australasian Structural Engineering Conference 2010, Sydney, N.S.W.: Engineers Australia, 2010: pg 64-69.