1. INTRODUCTION

Light gauge steel framing has established itself in Australia as a viable solution for the structural framing of dwellings, with over one in eight houses being constructed using steel framing. Steel framing is also increasingly being used in other low-rise buildings such as hospitals and schools. The industry is well established with a range of frame supply companies able to service and grow the market across Australia.

Australia has an urbanised population of 20.7 million of which over 60% live in major cities, with 40% concentrated in Sydney and Melbourne alone. The underlying demand for dwellings is approximately 160,000 per annum [1]. While allotment size is decreasing, the average house size is increasing. For instance in Victoria, the average house size has grown from 170 square metres in 1996 to 240 square metres in 2005 [2]. There is also a trend towards multi-level apartments.

2. FORMS OF HOUSE CONSTRUCTION

Traditionally Australian houses were constructed from either solid brick with a hardwood timber roof frame or timber weatherboard cladding on hardwood timber wall framing with a timber roof structure. After World War II, brick construction practice generally moved from solid brick to brick veneer as it proved a faster and more economical form of construction. It also provided the builder with more flexibility in programming the work as progress on the house was not determined by the brick layer, and fewer ‘wet trades’ were involved. Today however in Perth, Western Australia, the walls are virtually all solid brick. Similarly in North Queensland the walls are constructed using concrete blocks. In both locations the masonry manufacturers have run very effective marketing campaigns convincing consumers of the merits of their products over framed construction.

Softwood timber roof trusses were introduced in the 1970’s as hardwood became scarcer and more expensive. However in some States the roofs are still constructed on site from sticks of softwood or hardwood timber.

Roofs are typically clad with either terracotta or cement tiles or steel roof sheeting. Steel cladding represents over 50% of all new roofs and is being strongly promoted by BlueScope Steel.

Houses are predominately built on concrete slabs on the ground. However framed sub-floors are still used in housing particularly on sloping sites. The typical Australian traditional framing method with a framed floor is illustrated in figure 1.

3. HISTORY OF STEEL FRAMING IN AUSTRALIA

Kit homes with cast iron frames were imported from Britain into Australia in the 1850’s [3]. Examples of these homes survive today and have been classified by the National Trust for their historical importance. The next example of steel framing occurred after World War II where about 200 homes were constructed in Canberra using bitumen coated steel.

The modern development of steel frames commenced in the 1960’s and led to the development of the welded frame which is still the basis for many frames constructed today. The system was based on grade 300 galvanized steel with a typical thickness of 1.2mm. The studs were typically 75x35x1.2mm plain channels. Manuals were developed for the design, fabrication and erection of steel frames and trusses. At this time standard sections were rolled by the large roll formers and fabricated by small fabricators.

The next round of development commenced in the early 1980’s. At this time a number of technological advances occurred that strongly influenced the development of steel framing up to this day.

- The introduction of Numerical Controllers (NC) led to development of roll formers that could be programmed to cut to specified lengths, punch service and other holes, etc.
- The arrival of personal computers and workstations facilitated the development of software that could control these machines.

These advances led to the development of systems where the house design was entered into the computer system and the cutting information was fed electronically to the programmable roll former. This saved significant costs in manufacture due to error minimisation, material waste and work in progress.

In the late 1980’s, Australia led the world with the use of G550 steel in house framing. With the development of more complex shapes the advantage of the higher strength steel could be utilised and consequently the steel mass in a house was reduced. The thinner gauge members resulted in lighter
frames and trusses which assisted with speed of manufacture and installation. The thinner gauges of steel encouraged the use of alternative methods of connection in the shop assembly of frames and trusses e.g. clinching, rivets, screws. The thinner gauges also assisted the following trades i.e. plasterers, electricians, carpenters, plumbers, etc. in their ease of use of steel frames.

During this phase of development, Aluminium/Zinc alloy coating (Zincalume®/TrueCore®) replaced galvanizing as the preferred method of providing corrosion protection due to its superior performance, with a life of two to four times that of the galvanized product [4].

Today the steel framing industry in Australia is very innovative with many different systems. This creative and competitive environment has led to steel frames becoming a mainstream option for framing of houses and similar structures. All systems are designed to comply with the requirements of the Building Code of Australia [5] which references the NASH systems are designed to comply with the requirements of the option for framing of houses and similar structures. All environment has led to steel frames becoming a mainstream with many different systems. This creative and competitive

4. BUILDING WITH STEEL FRAMING

Steel framing offers significant benefits to the builder, other trades and the home owner.

4.1 Durability

Steel frames have proven themselves in Australia since the 1960’s to be a durable system, providing good building practice is adopted. This includes the use of fasteners with a similar life expectancy to that of the steel frame and with concrete slab construction, ensuring the perimeter of the slab is detailed to stop ingress of moisture (see figure 2). Steel-framed construction should generally be used further than 300 metres from breaking surf and 100 metres from still salt water.

![Figure 2: Slab edge detail](image)

BlueScope Steel provides a 50 year warranty on TrueCore®. Steel framing providing good building practice is followed [7].

One of the major advantages of steel framing in the Australian context is that it is not subject to damage by termites or borers such as the European house borer and the Lyctid borer. It has been estimated that the annual cost of termite damage in Australia is in excess of $100 million. Jeary [8] carried out a survey of houses in suburban Sydney where both steel-framed and timber-framed houses were constructed in similar numbers. The houses were generally less than 20 years old and one in eight timber-framed houses had suffered a termite attack. None of the steel-framed houses had suffered any damage. As termites can enter a steel-framed house and eat non-structural items such as architraves, it is recommended that in termite areas, the owner carries out regular inspections for the telltale signs of termite activity.

The timber industry has relied on ‘barriers’ or deflectors that work on the principle that the characteristic signs of termite activity will be picked up in an inspection and the termites exterminated before they do too much damage. Jeary’s study demonstrated that the barrier systems are not providing effective termite protection to timber-framed housing. The timber industry is now promoting chemically surface treated timber that provides a 25 year warranty against termite attack. This product now represents almost 20% of the market and is predicted to be used for as much as 50% of timber frames in three years from now [9]. Whilst masonry is resistant to termite attack, ‘barriers’ need to be installed in termite designated regions if any susceptible structural members are used in the floor or roof.

The only protection system for timber frames against borer attack is the use of treated timber.

4.2 Quality of construction

Steel frames are cut and assembled to tight tolerances [6] and this permits the installation of the frame to similar tolerances. Steel has the distinct advantage that it is does not warp or creep with time. Steel framing meets the requirements for the highest quality substrate specified in the plasterboard installation standard [10].

As the coefficient of thermal expansion for steel and plasterboard are very similar it is very unusual to experience cracking of the plasterboard in a steel-framed house.

4.3 Flexibility of design

The strength and stiffness of steel framing allows for long span trusses that offer freedom to design large open rooms and the potential to relocate non-load bearing walls as the needs of the household change. Light weight non-load bearing steel framed walls can be easily, quickly and cleanly changed to suit the new configuration of the house.

4.4 Speed of construction

Due to its high strength-to-weight ratio, steel provides lighter structural members that speed up construction. For an average 250 square metre house, a crew of two to three will typically erect the steel framing in three to four days.

For some building designs, the strength and rigidity of steel allows the steel trusses to be assembled on the slab, the steel roof sheeting to be attached to the roof and the whole roof assembly can then be lifted on to the steel walls. This method of construction is both faster and safer with many assembly operations performed at slab level. However it does not suit
all designs and space is needed to place the roof whilst sufficient walls are erected to take the roof load.

Veneer construction allows great flexibility in planning and does not rely on the speed of bricklayers for progress. This takes bricklaying off the critical path in the construction of the house. Service holes are provided in the stud walls which allows for fast installation of plumbing and electrical services. Fixing of plasterboard is significantly faster than hard plastering and avoids another wet trade. These benefits are achieved whilst maintaining the same outward appearance as a double brick house.

4.5 Environment

Environmental issues are receiving more attention particularly by designers in response to the green house debate. However there is much misinformation in the market place about different environmental benefits of different products. It is critical that any characteristics between different building products are compared on the same basis and the assumptions made in the analysis are clearly stated. NASH advocates that the best current method to compare products is to use Life Cycle Analysis (LCA) of the building. This includes the energy required to manufacture the materials, to construct the building, to operate the building and finally to demolish the building. This analysis should take into account the fact that all steel can be recycled. The operational energy in housing has been found to dominate the LCA analysis and the fact that all steel can be recycled. The operational energy

The advantages for steel framing in environmental terms include:

- With large open spaces provided by the steel solution, the building can be reconfigured to suit changing needs.
- Steel framing can be reused when the building is demolished.
- Steel is 100% recyclable.
- Wastage levels for steel in a fabrication plant with its own roll formers are typically less than 1%.

4.6 Cost

When comparing the costs of construction, it is necessary to include all relevant cost components to obtain a true picture. The costs that need to be considered include:

- Frame supply and erection.
- Termite treatment.
- Plasterboard installation.
- Electrical and plumbing services.
- Builders call backs due to defects.

Whilst the steel frame offers benefits such as flatter walls, no problems with nail popping and the provision of service holes, it has been very difficult to get the benefits recognised and valued. Trades often are able to charge a premium to work on steel frames due to market conditions. Similarly most builders include rectification work as an overhead and are therefore unwilling to give any credit for the reduction in call backs.

Consumers are generally willing to pay a small premium for the superior quality offered by a steel-framed home with its inherent termite resistance. Depending on the design and local market conditions steel frames can cost from slightly less to up to 15% more than timber.

Quantity surveyor, Rawlinsons [11] publish annually indicative pricing for various forms of construction. The data presented in this publication give indicative prices but do not necessarily reflect the discounts big builders obtain or that these could vary with different material suppliers.

Table 1 provides costs per square metre in each of the Australian mainland capital cities for different types of external wall construction. This demonstrates that cavity or double brick wall is significantly more expensive than brick veneer, even in Perth where brick construction is the standard form of construction. This, together with the longer construction time, lack of skilled bricklayers, the poor thermal insulation properties of brickwork and the move to more thermally efficient construction, has led to builders in Perth trialling veneer construction. Brick veneer with steel stud framing is 3 - 5% cheaper than timber-framed construction.

Table 2 provides the cost comparison for the roof with different types of cladding. In all capital cities, with the exception of Brisbane, steel roof framing is 20 - 25% more expensive than timber framing. However in Brisbane steel has a cost advantage of 8%. Steel trusses become increasingly more competitive for spans over ten metres.

<table>
<thead>
<tr>
<th>EXTERNAL WALL</th>
<th>ADELAIDE</th>
<th>BRISBANE</th>
<th>MELBOURNE</th>
<th>PERTH</th>
<th>SYDNEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavity brick wall</td>
<td>318</td>
<td>264</td>
<td>246</td>
<td>243</td>
<td>252</td>
</tr>
<tr>
<td>Brick veneer:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel stud framing</td>
<td>223</td>
<td>176</td>
<td>179</td>
<td>186</td>
<td>189</td>
</tr>
<tr>
<td>Timber framing</td>
<td>229</td>
<td>184</td>
<td>185</td>
<td>196</td>
<td>199</td>
</tr>
</tbody>
</table>

Notes:

1. The cavity wall consists of 2 leaves of 110mm wide clay bricks with 50mm cavity and hard plaster to the inside face. The outer face consists of face bricks and pointed finish. The cost of insulation required in Melbourne and western Sydney has not been included.

2. Brick veneer costs consist of external face brick, studwork, insulation and 10mm plasterboard internally.

Table 1: Comparative external wall costs (A$ per square metre of wall)
Table 2: Comparative roof costs (A$ per square metre of roof)

<table>
<thead>
<tr>
<th></th>
<th>ADELAIDE</th>
<th>BRISBANE</th>
<th>MELBOURNE</th>
<th>PERTH</th>
<th>SYDNEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel-framed roof with:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terracotta tiles</td>
<td>149</td>
<td>184</td>
<td>142</td>
<td>184</td>
<td>152</td>
</tr>
<tr>
<td>Concrete tiles</td>
<td>134</td>
<td>145</td>
<td>129</td>
<td>170</td>
<td>149</td>
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<tr>
<td>Steel roofing:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zincalume®</td>
<td>117</td>
<td>131</td>
<td>124</td>
<td>144</td>
<td>134</td>
</tr>
<tr>
<td>Colorbond®</td>
<td>123</td>
<td>137</td>
<td>130</td>
<td>151</td>
<td>140</td>
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<tr>
<td>Timber-framed roof with:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Terracotta tiles</td>
<td>121</td>
<td>197</td>
<td>115</td>
<td>151</td>
<td>139</td>
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<tr>
<td>Concrete tiles</td>
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<td>158</td>
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<td>143</td>
<td>101</td>
<td>117</td>
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<td>Colorbond®</td>
<td>100</td>
<td>148</td>
<td>107</td>
<td>123</td>
<td>131</td>
</tr>
</tbody>
</table>

Note: The costs for roofs cover the framed roof up to 10 metres overall span comprising trusses, rafters, battens and insulation and the indicated cladding.

Table 5. STEEL FRAMING SYSTEMS

5.1 Roof framing

Two distinct types of roofs are constructed using steel framing:

5.1.1. Panel system

This form of construction is shown in figure 3 and is modelled on traditional timber framing with rafters supported on strutting beams and ceiling joists supported on hanging beams. The roof rafters and ceiling joists are assembled into panels in the fabricator’s facilities and then erected on site. The light weight of the steel panels allows the frames to be manually handled both in the factory and on site. The rafter and joists are typically spaced at 600mm centres. One of the main advantages of this system is that it provides large open areas within the roof that allow good access for maintaining services and the provision of storage space provided this is included in the design. Blind rivets are used to connect the components together to form the panels and self drilling screws are used to connect the panels and beams together on site.

5.1.2. Truss system

The truss system is the most common roof system in Australia. The truss spacing is determined by the type of roof cladding (i.e. tile or steel sheeting), the strength and rigidity of the battens and safety guidelines for safe installation of cladding. Truss spacing varies around Australia from 1500mm centres in Western Australia to 600mm centres for tile roof and 900mm for steel sheeting and everywhere in between. As steel trusses are very strong and rigid, it is generally more economical to space them further apart. However this has been limited by safety guidelines that limit the spacing of trusses [12]. It is possible to increase this spacing if a ‘work method statement’ is developed to show it is safe to install battens and cladding on trusses spaced further apart. Some builders are reluctant to move outside the guidelines set by the Safety Authorities.

Truss chords typically use one of following sections:

- C channel - vertical or horizontal
- U section
- Z section

Figure 4: Truncated trusses with webs fixed to the external face of chord and supported on girder truss
Webs of trusses are usually channels. The webs can either be in the same plane as the chords or attached to the external face of the chord. This latter solution introduces issues of eccentricity in the design and is more difficult to stack efficiently, which usually involves a greater stacked volume and therefore fewer products per transport load.

At hip ends of roofs the roof can either be framed by a series of truncated trusses or by using hip and jack trusses.

### 5.2 Wall framing

Initially a 75mm stud depth was chosen for steel framing in Australia. Later 90mm and 70mm wall studs were introduced to match timber framing. The ability to match the local timber sizes reduces problems on site with the builder not ordering the right width door jambs or window reveals to suit the stud width. These differences can cause problems when designing a house as the designer does not know what width wall to allow for as the steel framer is usually not known at this time.

The wall stud sections (see figure 5) can be:

- Plain channel
- Lipped channel
- Box stud

The webs of the studs often have stiffeners rolled into them to increase their effectiveness, particularly with the thinner high strength G550 steels.

Lintels over windows are either trussed or an angle lintel to provide transfer of the load.

![Typical stud cross sections](image)

**Figure 5: Typical stud cross sections**

### 5.3 Floor framing

A wide range of floor systems has been developed for both the sub-floor and first floor. Typically the steel members are combined with a timber floor e.g. particle board, plywood or tongue and groove hardwood. The timber is glued to the steel and then mechanically fastened using screws or nails. To avoid squeaks in the floor, the nails or screws should not touch the sides of the floor members or webs of the trusses.

The floor system consists of floor joists at typically 450mm centres that are supported on bearers. These bearers can be either in the same plane as the joist or under the joists. The joists and bearers can be constructed from the following sections:

- C purlins
- Trusses
- Hollow sections
- Top hats

Webs of trusses should be attached to the top and bottom chord so that any relative movement between the web and chords does not cause any noise or the relative movement is stopped through providing sufficient connectors.

### 5.4 Bracing

The bracing is designed to take the lateral loads from the roof down to the foundations. The plasterboard ceiling and the timber floors are assumed to provide a rigid diaphragm. Tests have shown that the plasterboard walls are the most rigid part of the vertical bracing system and hence the plasterboard takes the horizontal loads whether it is designed to or not. Lateral bracing must be provided until the plasterboard is fixed and this normally represents 50 - 60% of the ultimate wind load. Steel lateral bracing can consist of:

- Steel tension cross bracing
- K Bracing
- Panel bracing using steel, fibre cement or plywood sheets
- Portal frame

It is important when mixing different types of bracing that there is enough ductility to ensure that all the bracing will be brought into play before failure.

### 5.5 Connectors

A wide range of connection types can be used with steel framing including:

- Welding
- Brazing
- Screws
- Rivets
- Clinching (see figure 6)
- Bolts

![Clinched connection of stud to bottom plate](image)

**Figure 6: Clinched connection of stud to bottom plate**

### 6. CODES AND STANDARDS

In Australia, the setting of building regulations is the province of the State Governments. Fortunately they unite with the Federal Government to form the Australian Building Codes...
Board (ABCB), which is responsible for the ongoing development of the Building Code of Australia (BCA). This document is then called up under State legislation or regulation to confer legal standing. Unfortunately the States still have their own amendments, although they have been reduced since the introduction of the BCA in 1996.

The BCA references Standards that confer them their legal standing. If a Standard is not referenced in the BCA it is reliant on being specified in the contract documents to have legal standing. Standards can now be developed by Standards Australia or other industry bodies provided they follow the protocols set by the ABCB. Consequently NASH was able to quickly develop its own NASH Standard – Residential and Low-rise Steel Framing Part 1 Design Criteria [5] and have it referenced in the BCA.

The NASH Standard sets out the design criteria to comply with the performance criteria of the BCA for steel framing of low-rise buildings including houses and low-rise commercial buildings. The NASH Standard allows the design to be carried out by:

- Calculation to relevant standards [13][14]
- Testing
- Combination of calculation and testing

When developing new systems, testing forms a large component of the design process as the cold-formed design standard is very conservative in places and it is not possible to model every item accurately.

As the ABCB Protocol for Standards limits the amount of advice that can be given, NASH is currently preparing a manual which gives guidance to designers on critical aspects of the design. This will assist designers to develop economical and safe designs.

The timber industry has developed Standards [15] that allow the design of structures without the need for structural calculations. These Standards are used by building designers, architects and draftsmen as well as engineers for the quick design of timber-framed houses. The steel industry has not had a similar document and has been severely disadvantaged because the design professionals have no suitable reference document to allow for simple design and specification. As a consequence an engineering certificate is usually required for each house which adds to the cost of steel framing. Additionally, as most engineers are not set up to undertake cold-formed design which is quite complex, they usually specify another product which is easier to design. Consequently NASH is working on Part 2 of its Standard which will include span tables to allow easy, safe design. It is planned that this Standard will be referenced in the BCA and this will place steel in a similar position to timber framing.

7. EDUCATION AND TRAINING

Education and training at both the professional and trade level are important elements in building the infrastructure necessary to facilitate the growth and prosperity of the steel framing industry.

Carpenters have traditionally been responsible for the construction of the timber frame and as the skills for erecting steel and timber framing are very similar, it is a logical extension that they also erect steel frames. Some State licensing systems require that licensed carpenters are responsible for the erection of steel framing.

Trades people are trained through an apprenticeship scheme where they receive their practical training from their employer and receive their theoretical and skills training from a Registered Training Organisation (RTO). The RTO can be either a government Technical and Further Education (TAFE) Institute or a private training provider. The typical apprenticeship lasts for four years and involves the apprentice attending their RTO for one week, eight times a year. The balance of their time is spent working for their employer. In response to the current industry skills shortage, there is pressure from sections of industry to compress this time or run more specialised courses in a shorter time.

The current carpentry apprentice course includes steel framing in the wall competency unit which is a core unit and steel framing is also included in some elective units. NASH is seeking to have steel framing included as a core unit in walls, floors, roofs and fitting out competency units.

In addition to actual frame erection, theoretical and practical steel framing skills need to be taught in the following trades:

- Plastering
- Electrical
- Plumbing
- Bricklaying

At some RTOs this is already occurring and NASH is working to influence more RTOs to follow this lead.

Although steel framing has been used in Australia for over two generations, professional education is not yet well established. The following professions need further education in steel framing:

- Structural Engineers
- Building Surveyors and Inspectors
- Architects
- Building Designers

The release of Part 1 of the NASH Standard provided an opportunity to hold seminars on the use of steel framing. These seminars have been very well received and the program will be increased as further parts of the Standard are published.

8. MARKETING

Steel framing initially found a ready market amongst owner-builders, who were generally well informed about product performance and prepared to accept slightly higher costs for the framing and trade services. As the industry grew, progressive builders were targeted to use steel framing in all or part of their houses. Some of those builders now make their own steel frames.
Today steel framing is often targeted at second and third owners who are prepared to pay a little bit extra for a quality product. Direct promotion of product benefits to the home owner has been effective in stimulating demand and helping to persuade builders to offer a steel framing option.

9. NASH

The National Association of Steel-Framed Housing (NASH) was formed in 1982 to foster the development of the steel framing industry. It represents the interests of steel frame fabricators, their suppliers and customers. It has currently about 100 members spread across Australia.

NASH’s key objectives are:

- Support the long term growth and sustainability of the Steel Frame industry
- Maximise the profile of Light Gauge Steel Framing within the building industry
- Maximise the value of belonging to NASH, for all membership categories
- Support the awareness and promote the advantages of steel framing in the Market Place

NASH is currently focusing its activities on the following projects:

- Develop and implement a national training approach to Steel Frame fabrication and erection capability
- Develop, monitor and maintain the NASH website
- Develop and implement a specific plan to deal with the current ‘Working at Heights’ issues
- Develop an improved ‘Member Value Proposition’ for all membership categories
- Promote the NASH Standard for steel framing and develop the accompanying manuals.

10. THE FUTURE

Steel framing is at an exciting time in Australia. The industry has increased its market share of housing from 7% in the 2002 financial year to 12% in 2005 with some regional areas gaining market share of over 30%. The industry is financially stable and in a position to expand to grow the market in steel framing. NASH predicts the market share growing at a steady pace over the next couple of years despite more aggressive competition from the timber industry.

Low rise non-housing applications will continue to grow as steel framing has now become the preferred solution for retirement villages and is becoming increasingly popular for schools and hospitals.

One of the challenges for the industry is to increase its share of the apartment market as policy makers encourage city consolidation to make better use of existing infrastructure and in an attempt to minimise the growth of the urban sprawl. Steel framing is starting to replace masonry construction in the apartment market for non-load bearing walls. In North America load bearing steel framing is regularly used on apartment buildings [16].

11. ACKNOWLEDGEMENTS

A special thanks to Michael Kelly and Lex Somerville for their contributions and feedback on this paper.

12. REFERENCES

[14] Standards Australia, AS/NZS 4600:2005: Cold-formed steel structures