Cold-rolled portal frames

David Brown, Deputy Director of the Steel Construction Institute, provides timely advice on what engineers should watch for when working with any of the portal frame structures being introduced to the UK market from Australia.

Over recent months structural engineers may have noticed advertisements for modest span portal frame structures, typically in local press and on the internet. Sold as a complete building and formed from cold-formed lightweight members, the style of structure is often a single span portal frame, or a so-called 'American Barn' having two monopitch side spans meeting the columns of a central portal span (Figure 1).

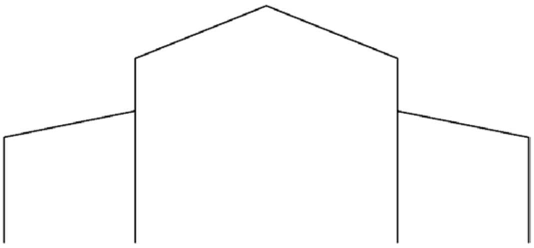

Figure 1. 'American Barn' structure

This form of structure constructed of cold-rolled members is very common in Australia, where such structures are often sold in this way, directly to the end client. This article sets out some of the technical issues that must be considered when transferring the technology to the UK. The comparison is with Australian practice, as this appears as the source of many of the companies now active in the UK.

UK Regulations

Although Building Regulations in the UK simply demand a safe structure (and thus permit design to any design Standard), common practice is to determine loading and structural resistance by reference to the appropriate British Standards. Thus it is important that any design needs to be proven by reference to the British Standards – which may be difficult if member sizes and details are simply imported into the UK without further consideration. Common practice is to demonstrate adequacy by calculation rather than by test, which means that buildings that actually have the same structural resistance may well have different calculated resistances according to different codes. Unless physical tests are undertaken, demonstrating adequacy by calculation is the only option.

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	Dead	Imposed	Wind
	1.4	1.6	
	1.2	1.2	1.2
	1.0		1.4
	1.25	1.5	
	1.25		1.0
	0.8		1.0

Table 1 Comparison of UK and Australian combination load factors

Loads and Load combinations

We Brits are familiar with imposed roof loads as a minimum or 0.6kN/m². It appears that Australian imposed loads may be as low as 0.25kN/m² which is a hugely significant reduction. We are also familiar with the load combinations shown in Table 1, and contrasted with those found in Australian designs.

Assuming a dead load of 0.2kN/m² typical ULS gravity loads are as follows:

UK: $1.4 \times 0.2 + 1.6 \times 0.6 = 1.24\text{kN/m}^2$

Australia: $1.25 \times 0.2 + 1.5 \times 0.25 = 0.63\text{kN/m}^2$

This is obviously a very significant difference, especially as in the UK it is common that the gravity loadcase is critical for strength.

Designers should also carefully consider service loading, and allow for this if necessary. A typical service load would increase the ULS gravity loads by 17%.

No extensive comparison of the wind loading in UK and Australia has been undertaken. However, UK designers will be familiar with the often onerous effect of positive (downward) coefficients on rafters as described in BS 6399-2. These positive coefficients appear absent in the Australian Standard, which is a further significant difference.

Material strength

Designers and checkers should be careful about the yield strength of the cold formed members assumed in design. Yield strengths of 450 N/mm² are common in Australia; in the UK, 350 N/mm² is typical, which represents a 22% reduction in strength.

Connections and Restraints

At eaves and apex connections, joints are often made using bolts and flat plate as shown in Figure 2, or plate with pressed indentations for increased strength and stiffness. There has been much research and testing of such connections and these may obviously be used

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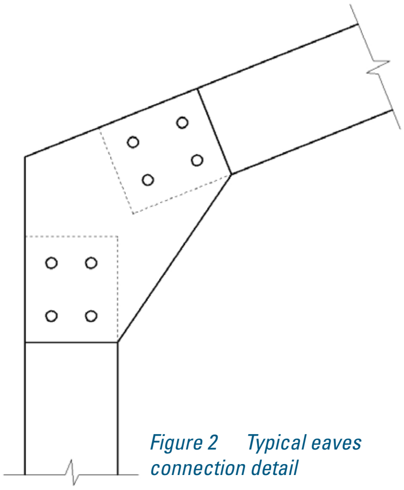

Figure 2 Typical eaves connection detail

with confidence in the appropriate circumstances. Clearly, designers and checkers should be reassured that the details are appropriate, and have not simply been detailed to look similar. Connections formed from bolts and thin plate are likely to be semi-rigid, and in the absence of other information, this flexibility should normally be accounted for in design. It may be that tests have demonstrated that particular approaches to design, combined with particular details, produce entirely satisfactory structures. If this evidence is not available, caution is advised.

Pay particular attention to the inside of the haunch connection

Australian practice for connection plate strength is also significantly different from common UK design. Typically, connection plates in Australian designs may be 480 N/mm^2, considerably higher than common UK practice.

Detailing is always critical – to realise the assumptions made in design. Designers and checkers should pay particular attention to the inside of the haunch connection, as shown in Figure 2, which will have an enthusiasm to buckle out of plane. If there is no restraint, and no test data to demonstrate adequate performance, how is buckling prevented?

Bracing, side rails and purlins

Bracing is commonly narrow, thin gauge material that is commonly delivered in a roll and is often fixed between the side rails and the cladding. To UK design Standards, such bracing may be difficult to prove as adequate. In reality, the cladding and roof sheeting is probably providing the resistance to shear and longitudinal forces. If no test evidence is available, it may be possible to demonstrate adequate resistance by utilising stressed skin action, and designing in accordance with BS 5950-9.

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In Australian practice, purlins and side rails are often so-called 'top-hat' sections, as shown in Figure 3. These profiles are not common in the UK; Designers should reassure themselves that the resistances to load, including the effects of pressure and suction, are adequate.

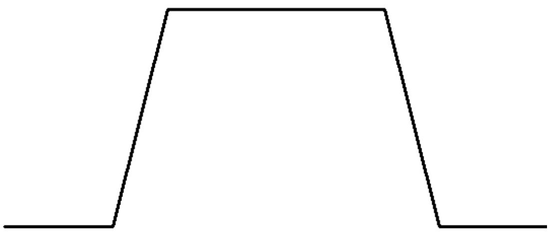

Figure 3 Typical 'Top Hat' section

In-plane stability

There is no excuse for ignoring in-plane stability just because the members are cold formed. The rafters will still have axial load in them, and the frames subject to second-order effects. The Australian design Standard has code provisions that will be familiar to UK portal designers, proposing either a second-order analysis, or a first-order analysis and amplification to allow for second-order effects.

The 'Australian' amplifier is the factor $\dfrac{1}{1-\left(\dfrac{1}{\lambda_{cr}}\right)}$

which UK designers will recognise as $\dfrac{\lambda_{cr}}{\lambda_{cr}-1}$

Analysis and Design

Issues to consider during analysis include the connection flexibility and base fixity. Most common base details appear to involve a pair of cleats bolted through the web of the column member. This appears to be relatively flexible compared to orthodox hot-rolled base details, so it is recommended that a pin be assumed in design.

Some iteration is likely in analysis and design, as the members are relatively small, and sensitive to modest changes in member loads. The amplifier to allow for second-order effects may vary quite significantly if members vary. A crucial influence on the amplification factor will be the relationship between the actual compression in the rafters and their elastic critical buckling load; the latter may change dramatically as the members change size.

It is not uncommon to find that adequate resistance can only be provided by utilising back-to-back members – this will change the analysis results significantly, and may well force further changes to other members.

Design in the UK will be to BS 5950-5. Though this may initially appear complex to designers used only to the design of hot-rolled members, the calculations of strength are straightforward. Shear resistance, and the resistance to shear and bending combined will more often be critical checks than is the case in hot-rolled design.

Conclusions

There are obvious risks in 'importing' any technology directly to the UK without proper consideration of any important differences in practice. Designers (and particularly those checking calculations) need to ensure that design assumptions are made in accordance with the UK Standards and are realised in the structural details, or that test results are available that demonstrate satisfactory performance.

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