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STEEL-FRAMING FACTS

Thermal and Energy Efficiency

The thermal efficiency of a building envelope is a function of the thermal performance of the planar elements (e.g. wall, roofs, windows), the local heat losses that can occur around them and where the planar elements are penetrated by building components. These local heat losses are the result of areas of the envelope where the thermal insulation is impaired. These areas of impaired thermal insulation are known as ‘thermal bridges’ or ‘cold bridges’.

The parameter used to express the thermal performance of a planar element is its R-value. The R-value is the overall thermal resistance of a building element to heat transmittance. Higher R-values relate to higher levels of thermal insulation and are expressed in units of square metre Kelvin per Watt (m^2K/W); in other countries U-values are often used, which are simply the reciprocal of the R-value and are expressed in W/m^2K (e.g. the lower the U-value, the higher the thermal resistance, or R-value, of an element).

NZBC, Clause H1 concerns itself with the energy efficiency requirements of buildings. According to Clause H1, acceptable methods for determining the R-values of building elements are contained in NZS 4214 and in the BRANZ House Insulation Guide. NZS 4218[1] outlines the following three approaches that may be utilised to demonstrate compliance:

1. The Scheduling Method involves selecting the required level of insulation from a tabulated set of minimum requirements. To enable this method to be utilized, the area of glazing should be 30% or less than the total wall area.
2. The Calculation Method uses a simple calculation of heat retention that can be no worse than that of a reference building. It allows the use of components with different thermal resistance values. To enable this method to be utilized, the area of glazing should be 40% or less than the total wall area.
3. The Modelling Method uses a computer modelling technique where the building design under consideration should not use more energy than a reference building design.

The most common method of compliance for volume housing is the Scheduling Method. Tabulated minimum wall R-values for each of the three climate zones in New Zealand are as follows:

- Climate Zone 1 and 2 = 1.9 m^2K/W (North Island, excluding Central Plateau).
- Climate Zone 3 = 2.0 m^2K/W (South Island and Central Plateau).

Typically, light steel framing in New Zealand and Australia follows traditional ‘cold frame’ construction where all of the insulation is included within the thickness of the wall studs; for these designs, the studs entirely bridge the insulation layer. Conversely, in Europe, ‘warm frame’ construction is common, which places all of the insulation outside the frame.

Steel has a high thermal conductivity compared with many other construction materials, which is normally taken[2] as $\lambda = 47.5$ W/mK. The high thermal conductivity means that steel construction systems, both the structural frame and cladding, must be carefully designed to minimise unwanted heat flows. For some buildings there may be situations where structural steel elements penetrate

[1] NZS 4218: 2009 Thermal insulation - Housing and small buildings, Standards New Zealand, Wellington
[2] Building Code of Australia, Section J Energy Efficiency, Specification J1.2 Material Properties, Australian Building Codes Board, 2010

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the insulated envelope or be fixed to other steel components, such as balcony brackets and brick support units. These areas require careful consideration. There are three ways of reducing thermal bridging in steel construction:

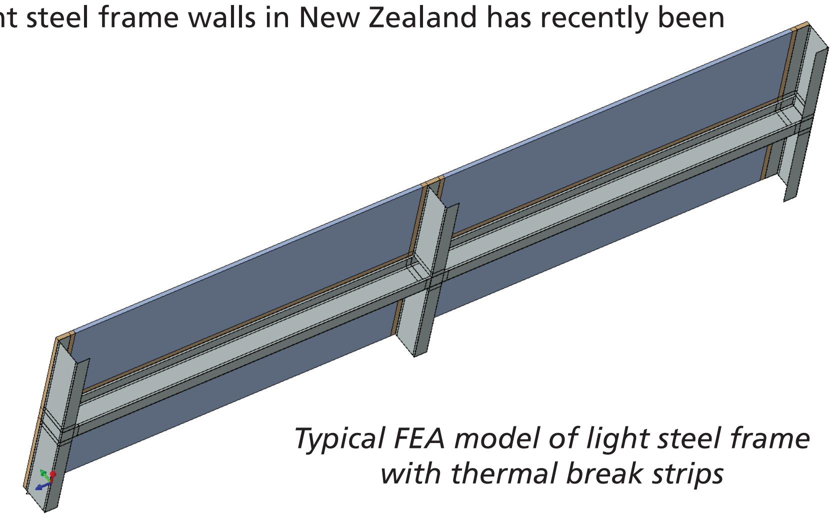
a) Eliminate the thermal bridge by keeping the steelwork within the insulated envelope.

b) Locally insulate any steelwork that penetrates the envelope.

c) Reduce the thermal transmittance of the thermal bridge by using thermal breaks, changing the detailing or by including alternative materials.

The introduction of thermal breaks at the interface between the frame and the external cladding given in option (c) is normal in light steel framing in New Zealand. According to the National Association of Steel-framed Housing[3] (NASH) a thermal break must be provided on the external face of each steel framing member and shall possess a minimum R-value of 0.25 m^2K/W. The thermal breaks may consist of Expanded Polystyrene (EPS) or Extruded Polystyrene (XPS) and can be provided as discrete strips with a width corresponding to flange dimension of the steel studs or, alternatively, through a continuous sheath that covers the entire wall.

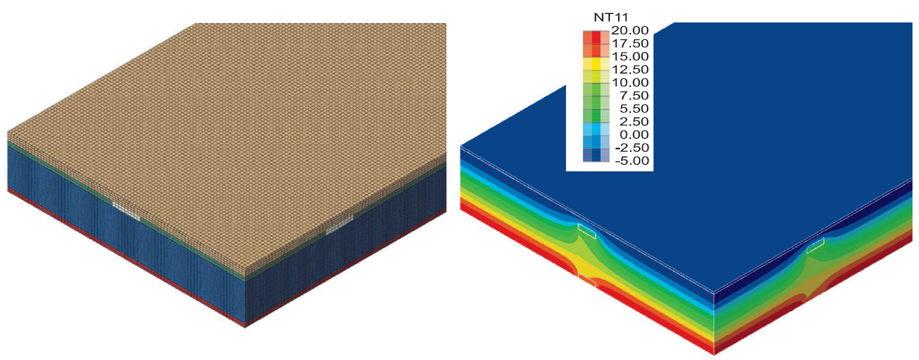
The thermal resistance of typical light steel frame walls in New Zealand has recently been evaluated by HERA using three-dimensional finite element analysis (FEA) models, which had been validated according to the requirements given in ISO 10211[4] as well as being calibrated against physical test data. In this study, 90 mm thick insulation with a thermal resistance of between R2.2 to R2.8 was considered for weatherboard cladding, sheet cladding and brick veneer. Both EPS and XPS sheets, as well as XPS sheath thermal breaks were considered, as well as the influence of cavity ventilation. A typical FEA model is shown below.



Typical FEA model of light steel frame with thermal break strips

The results from a typical thermal analysis are shown below for a light steel frame using strip thermal breaks. The figure on the right shows the temperature distribution from the external face of the weatherboard cladding (shown in blue) to the internal face of the plasterboard (shown in red); the discrete changes in temperature along the sides of the model, correspond to the locations of the steel stud and nog.

The main findings from this comprehensive research programme were as follows:



Weatherboard cladding, 12 mm thick EPS thermal break, R2.2 insulation. Temperature distribution (right).

- Light steel framed walls with an unventilated cavity easily satisfy the minimum R-values for Climate Zone 1, 2 and 3 according to the Scheduling Method given in NZS 4218.
- For sheet cladding, a 10 mm XPS sheet over the whole of the wall inside the building wrap produced R-values that were similar in magnitude as a timber framed wall with direct fix sheet cladding.

3 N-11 NASH House Insulation Guide, National Association of Steel-framed Housing, Manukau City

4 ISO 10211: 2007 Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations, International Organization for Standardization, Geneva

Condensation

Condensation in buildings can occur on a cold internal surface, or as interstitial condensation within the thickness of the wall. The latter case can be more serious as it can go unnoticed, leading to damage of the fabric of the building. Water vapour will pass between spaces or across envelope elements wherever there is a vapour pressure difference. Where vapour-laden air percolates into a wall, floor or roof construction, it will lead to interstitial condensation if it is cooled to its dew point temperature. In light steel construction, interstitial condensation on the steel is avoided by keeping the steel frame within the insulated cavity, or ensuring that there is an effective vapour barrier to prevent water vapour reaching the cold part of the envelope. The increased thermal conductivity of steel studs means that the temperature of the steel along the web and at the outer flange is greater than in the insulation alongside, which eliminates the build-up of condensation for extended periods of time on the wall studs.

In the worst case, thermal bridging through the studs can cause local cool spots in the vicinity of the stud, leading to "ghosting" where local condensation causes staining of the wall surface along the lines of the studs. To avoid surface condensation and ghosting, the Building Research Establishment (BRE) in the UK suggests[5] that internal surface temperatures should not fall below 15.5°C when the internal air temperature is 21°C. In the research conducted by HERA it was shown that, for typical light steel framing used in New Zealand, the internal surfaces temperatures never fell below the BRE limit where ghosting would become a problem. Nevertheless, irrespective of whether steel is used as a framing material, in the context of condensation and ghosting, particular attention must also be paid to:

- Detailing to ensure continuous insulation at window and door openings.
- Detailing at wall junctions with floor and roof.
- Penetration by services.
- Mechanical venting of spaces subject to high humidity, e.g. bathrooms.

5 Building Research Establishment, Energy efficiency in new housing. Lower energy design for housing associations, Good Practice Guide 79, 1993