Technical Recommendation

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A Test & Evaluation Method of Systems to Provide 60 Minutes Fire Resistance for Nailed Gusset Connections

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RELEVANCE

Timber portal frames supporting fire rated external walls are frequently required to have a Fire Resistance Rating (FRR) of 60 minutes, the FRR being defined in NZS 1900 Chapter 5 (1988). The fire resistance of individual members of such structures can be assessed by using the residual section of these members, based on the 'sacrificial method of char' outlined in MP9:1989. To ensure the structural integrity of the portal frames, nailed connections between members are also required to achieve the same FRR.

While building roofs are not usually required to be fire rated, the structural portal frame must remain stable under the imposed load for the duration of the FRR period. Thus, individual columns, beams and joints must all possess the required FRR, unless a change of structural action is specifically allowed for by the design. One example is to design the column to have cantilever action, in which only the column members need to be fire rated.

This Technical Recommendation outlines a comparative test and evaluation method using small-scale unloaded specimens, to demonstrate that a particular protective system can be used over nailed gusset connections to achieve a 60 minutes FRR.

SCOPE and ACCEPTANCE

This Technical Recommendation is suitable for assessing protection on nailed gusset connections in portal frames where the live load is less than 0.4 kPa, typical of those supporting a roof system. The protection of moment resisting nailed gusset connections in timber framed buildings, with a live load exceeding 0.4 kPa, is beyond the scope of this Recommendation.

This Recommendation is applicable to all species of timber in which the actual designed structural members are able to achieve a 60 min FRR. Portal frames constructed of glue-laminated (glulam), solid timber, laminated veneer lumber, and other wood-based products which are solid, and which satisfy the previous requirement are within the scope of this Recommendation. However, portal frames using hollow sections such as plywood box beams are outside the scope.

Protected nailed gusset connections, evaluated and tested in accordance with the method detailed in this Recommendation, are recommended to be accepted as achieving a maximum FRR of 60 minutes. The protection details which are tested must be used in practice. The thickness of protection, the extension of the protection beyond the edges of the gusset, and the fixing of the protection to the portal frame member and/or gusset shall be as those tested.

The method is applicable to gussets that have a minimum thickness on each face of 5 mm for steel, or 30 mm for plywood. Where a plywood gusset of greater than 30 mm is tested, the 60 minutes FRR for the protection material shall only apply to a construction using plywood with that minimum thickness on each face.

SPECIFICATION

Materials

The specimen shall be fabricated using glulam timber from untreated Pinus Radiata of No. 1 Framing Grade as specified in NZS 3606:1979. The plywood used for the gusset material shall be of Grade Cp-D, and manufactured as specified in NZS 3614:1971. Both the glulam specimen and plywood gusset shall be conditioned such that their moisture content at the time of testing does not exceed 12%. The steel used for the gusset material shall be Grade 250 mild steel, as specified in AS 1204:1980.

The protection material shall be manufactured and installed in accordance with the specification of the manufacturer.

Construction

The angled knee (or apex) joint shall be modelled by a

specimen which is fabricated from a single piece of glulam timber, using laminations 40-45 mm thick. It shall have minimum dimensions of 450x90 mm wide, with a minimum of 650 mm being immersed in the furnace. The end of the glulam shall be protected with a sheet material which is identical to a sheet material used in an approved light timber frame partition system with 60 minutes FRR, to simulate a greater length than tested.

Gussets shall have minimum dimensions of 450x450 mm with a minimum thickness on each face of 5 mm for steel, or 30 mm for plywood. Where two or more sheets of plywood are laminated to achieve this thickness, the full contact surface area between the sheets shall be glued using Resorcinol glue, and clamped for not less than 24 hours before testing.

The protection material shall be applied to four surfaces of the specimen, i.e. the top and bottom, and the two vertical faces (refer sections A and B, Figure 1). The protection material shall be cut from a single sheet, without any joints. It is recommended that the protection extend 50 mm beyond the edges of the gusset to preclude fire attacking the connection from there. Other detailing may be used.

Fixings

The protection material shall be fixed to the glulam, or the gusset, or both, in accordance with the specification of the manufacturer.

The gusset shall be attached to the glulam using four 3.15x75 mm flathead nails, 40 mm in from the two edges, one at each corner of the gusset. Holes of 3.20 mm diameter shall be predrilled in the steel gusset.

Test Method

The test shall be carried out in a furnace with minimum clear dimensions of 1.0x1.0 m. The specimen shall be set-up such that the two vertical faces and the top and bottom surfaces be fully subjected to the furnace conditions. One method of mounting the specimen in the furnace, by bolting the end of the glulam to a stud of the timber framed furnace cover, is shown in Figure 1. Only a single specimen located in the central zone of the furnace shall be tested each time.

The distance from the back wall of the furnace to the end of the glulam shall be at least 100 mm.

Steel gusseted specimens shall have five stainless steel sheathed thermocouples installed on each face (a total of 10), to measure the temperature on the glulam surface beneath the steel gusset (on the glulam-gusset interface). Four of these thermocouples shall be positioned 60 mm in from the two edges, one at each corner of the gusset. The fifth thermocouple shall be positioned at the centre of the gusset (Figure 1). Plywood gusseted specimens shall have five stainless steel sheathed thermocouples attached to the glulam surface in the same locations as for the steel gusset. In addition, five thermocouples shall be installed in the same position but on the outer face of the plywood gusset beneath the protection material (on the gusset-protection interface).

Each test shall consist of one type of gusset (steel or plywood) and one protection system.

The test shall be conducted in accordance with ISO 834:1975, except as noted elsewhere in this Recommendation. The furnace shall be driven to the 'standard' time-temperature

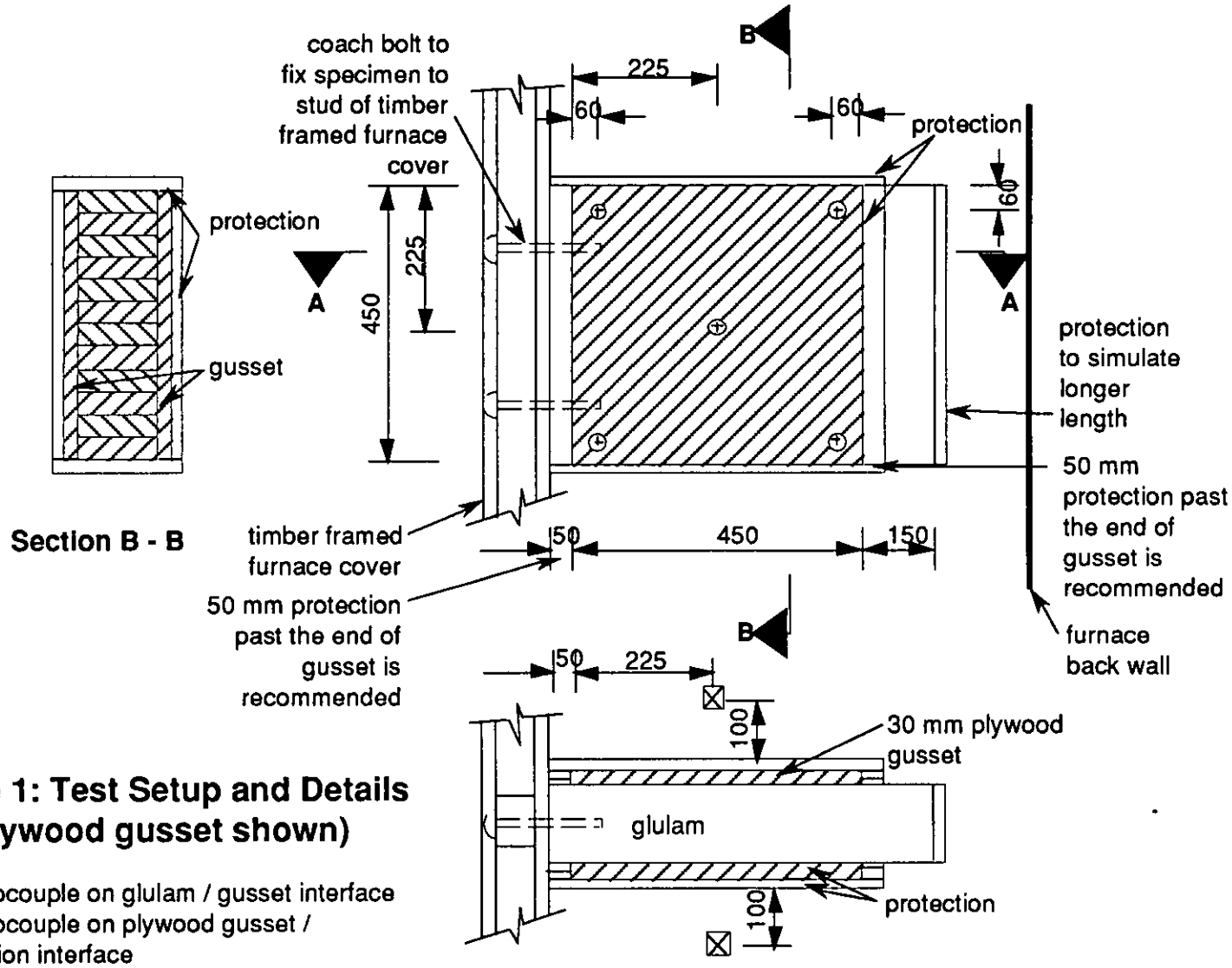

Figure 1: Test Setup and Details (plywood gusset shown)

+ Thermocouple on glulam / gusset interface
○ Thermocouple on plywood gusset / protection interface
⊠ Thermocouple to measure furnace temperature

curve based on the average temperature of two Type K chromel-alumel thermocouples, 100 mm from the outer surface of the centre of the protection material.

Evaluation

The performance of the protection system shall be evaluated by considering the average temperature at the glulam-gusset interface for both steel and plywood gussets, and also from the average temperature of the gusset-protection interface of the plywood gusset. In each case, the average temperature shall be determined from the average of the thermocouples at the interface under consideration.

Two criteria shall be used to determine if the protection material on a nailed gusset connection can achieve 60 minutes FRR. The average temperature at 60 minutes, and the average time before the glulam or plywood commence charring shall be as specified in Table 1. Charring of both glulam and plywood is assumed to commence at 300 degrees Celsius, with an assumed ambient temperature of 20 degrees Celsius.

	Steel Gusset	Plywood Gusset
Time (minutes) for average temperature on the glulam surface to rise 280 degrees Celcius	> 43	NA
Average temperature rise on glulam surface at 60 minutes degrees Celcius	< 445	< 85
Time (minutes) for average temperature on the plywood surface to rise 280 degrees Celcius	NA	> 41
Average temperature rise on plywood surface at 60 minutes degrees Celcius	NA	< 500

Table 1: Conditions to Achieve a 60 Minute FRR

The protection material shall be deemed to have provided a 60 minutes FRR to steel gusseted nailed connections when :

(a) the time for the average temperature on the glulam surface to rise 280 degrees Celsius is greater than 43 minutes, and;

(b) the average temperature rise on the glulam surface at 60 minutes is less than 445 degrees Celsius.

For plywood gusseted nailed connections, the protection material shall be deemed to have provided a 60 minutes FRR when :

(a) the average temperature rise on the glulam-gusset interface at 60 minutes is less than 85 degrees Celsius, and;

(b) the time for the average temperature on the glulam surface to rise 280 degrees Celsius is greater than 41 minutes; and;

(c) the average temperature rise on the gusset-protection interface at 60 minutes is less than 500 degrees Celsius.

BASIS OF RECOMMENDATIONS

Full-size loaded beam tests, and pilot tests have been carried out at the Building Research Association of New Zealand (Yiu and King, 1989; Lim and King, 1990) on nailed gusset connections protected with a 'gypsum-based' board. The specimens were subjected to 60 minutes of the ISO 834:1975 time-temperature conditions.

The 'loadbearing capacity' criterion of BS 476 Part 20: 1987 and AS 1530 Part 4: were used to assess the performance of the protected nailed connections in the full-size tests. The results indicated that up to 60 minutes, the rotation within the joints, and the deflection of the specimens were significantly lower than the specified limits. The results of other simulated tests carried out at the University of Canterbury (Chinniah, 1989) established that deformations in a portal frame due to joint rotations were much less than those due to charring of members away from the joint. The performance of protected nailed gusset connections can therefore be related to the glulam and gusset temperatures beneath the protection material. If the temperatures beneath a protection material satisfy the above evaluation criteria, they can also be considered to provide 60 minutes FRR to the nailed gusset connections.

Pilot tests were carried out using the same 'gypsum-based' board protection to obtain the required comparative temperatures and time of Table 1.

RELEVANT DOCUMENTS

AS 1204:1980. Structural Steel. Ordinary weldable grade. Standards Association of Australia.

AS 1530 Part 4: 1985. Fire resistance tests of elements of building construction. Standards Association of Australia.

BS 476 Part 20:1987. Fire tests on building materials and structures: methods for the determination of the contribution of components to the fire resistance of a structure. British Standards Institute.

Chinniah, Ramu. 1989. Fire performance of nail gusset connections between heavy glulam members. Research Report No. 89/6. Department of Civil Engineering, University of Canterbury, Christchurch.

ISO 834:1975. Fire-Resistance Tests - Elements Of Building Construction. International standards Organisation.

Lim, K.Y.S. and King, A.B. 1990. Protected nailed gusset connections for glulam members. Building Research Association of New Zealand. Study Report SR 29. Judgeford.

NZS 1900 Chapter 5:1988. Fire resisting construction and means of egress. Standards Association of New Zealand (SANZ).

NZS 3606:1979. The manufacture of glue laminated timber. SANZ.

NZS 3614:1971. Specification for the manufacture of construction plywood. SANZ.

MP9:1989. Fire properties of building materials and elements of structure.

Yiu, P.K.A. and King, A.B. 1989. The fire performance of unloaded nailed gusset connections for fire-rated timber members. Building Research Association of New Zealand. Study Report SR21. Judgeford.

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