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TECHNICAL REPORT NO. 62

Static Testing of Batten Connections at University of Western Australia

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Bibliography.
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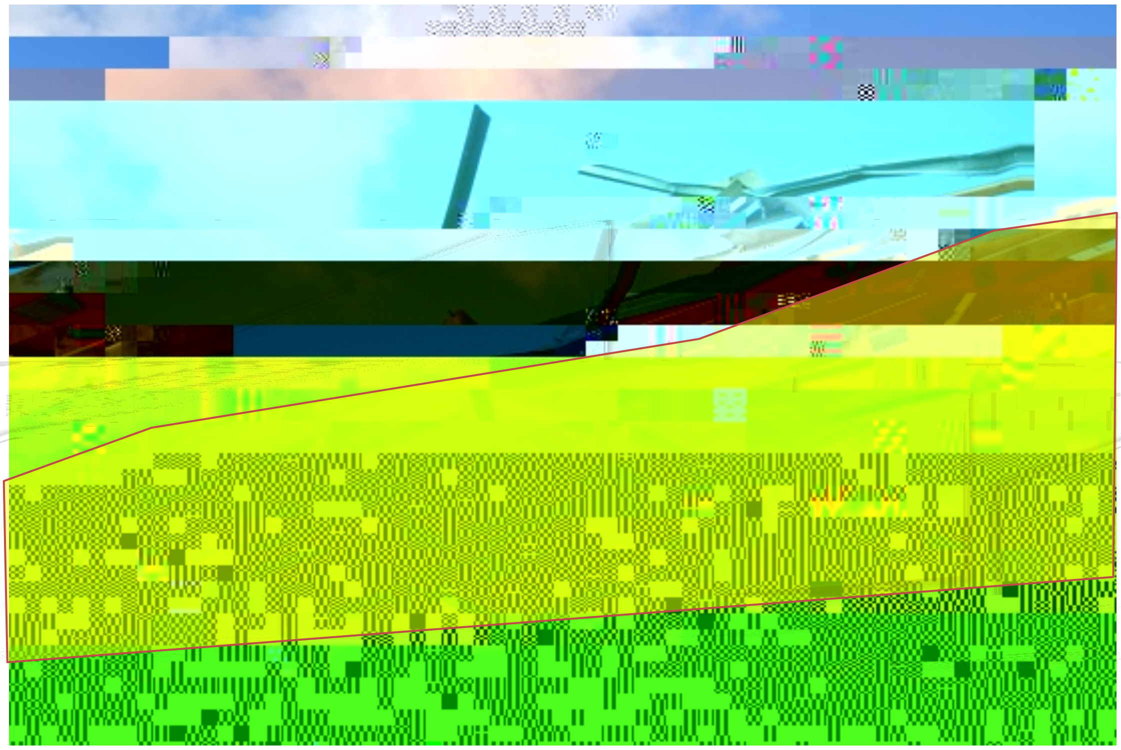
1. INTRODUCTION

1.1. Batten to rafter connections in practice

Failure of batten to rafter or batten to truss connections have been identified in investigations of wind damage in Australia pulled over the nail heads near the edge of the roof, and progression of the failure tore roofing fasteners out of the battens near the ridge.



Other roofs are constructed with timber battens. The 90 x 35 battens shown in Figure 1.3 can use connections selected directly from AS 1684.2 (Standards Australia 2010a), as the assumed batten depth in the Standard is 38 mm. However, the battens in Figure 1.4 are 45 mm deep so the connectors do not have the same depth of penetration into the rafter assumed in AS 1684.2. Hence the capacity of these connections cannot be directly obtained from AS 1684.2.

Batten connections to trusses or to rafters have the same loads, the same load transfer mechanism and the same capacity. In this report, batten to rafter and batten to truss connections are both referred to as batten to rafter connections.

Section 2 details three undergraduate research projects

- Screwed connections between top-hat battens and MGP10 rafters. These connections are recommended by a batten manufacturer (Lysaght 2014).
- Screwed connections between 35 mm and 45 mm thick timber battens and MGP10 rafters. In many cases, 75 mm bugle head screws are used on both 35 mm and 45 mm thick battens.

1.2. Selecting batten to rafter fasteners from AS 1684

Figure 1.5 shows the uplift force on a batten to rafter connection for the following example:

- Wind Region A;
- Wind classification N2;
- Sheet roof;
- Rafter spacing 900 mm;
- Batten spacing 900 mm;
- Edge zone

The uplift force for this example is 1.5 kN.

The uplift force

AS 1684.2 (Standards Australia 2010a) provides deemed-to-satisfy solutions referenced by Volume 2 of the National Construction Code for many connections in domestic construction. However, it does not provide connection capacities for the following connections observed in practice in WA:

- Nails into the flanges of steel battens;
- Screws into the flanges of steel battens; and
- Screws into 45 mm thick softwood battens

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2. LABORATORY TESTS

2.1. Sampling

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The rafters were commercially available 120 x 35 MGP10 timber selected to give a wide range of densities. The densities of the supplied timber were between 438 and 618 kg/m^3. The rafters were cut into 900 mm length specimens. The specimens were divided into groups to give similar average density and standard deviations in each test group. Figure 2.1 shows:

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A local building inspector supplied samples of a number of different top-hat batten products for the preliminary tests (see Section 2.4). The preliminary tests were used to select a specific top-hat batten profile for testing from a number that are commonly used on housing projects in Perth WA. The TS4055 battens, Lysaght Topspan 40 0.55

2.3. Testing equipment

The equipment used in the test program included:

- A Universal test machine set to a loading rate estimated to produce time to failure between one and five minutes;
- A loading frame consisting of two U-shaped bearing elements that provided tension between the rafter and the batten as the UTM platens were moved closer together.
- A loading plate that distributed tension loads to five roofing screws that were used to apply the load to the batten in a realistic manner (see Figure 2.3).
- Load cell attached to the test machine to provide accurate force measurements;
- A laser displacement transducer was used to measure relative deflection between the batten and rafter. This provided a measurement of deflection of

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2.5. Main test program

Four configurations of batten to rafter connections were tested:

- One Buildex® No.14 Type 17, 75 mm length bugle head screws into 35 mm thick timber battens;
- One Buildex® No.14 Type 17, 75 mm length bugle head screws into 45 mm thick timber battens;
- Two 57 mm Ortons hot-dipped galvanised smooth shank nails into Lysaght Topspan 40 0.55 mm BMT steel roof battens;
- Two 40 mm M5.5–11x40 Batten Zip® screws* into Lysaght Topspan 40 0.55 mm BMT steel roof battens ;

*Note: Batten Zip® screws are recommended by Lysaght (2014) for use with Lysaght TS4055 Topspan steel roof battens into timber rafters.

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2.6.

3. TESTS ON TIMBER BATTENS

Two series of tests were conducted on timber battens. The fasteners for each were one Buildex® #14 Type 17, 75 mm long bugle head screw. Section 3.1 presents the results and discussion of the tests on 35 mm thick timber battens (a configuration for which design values are given in AS 1684.2) and Section 3.2 presents the results and discussion of the tests on 45 mm thick timber battens.

In the 35 mm batten test program, some fasteners failed by pull through in the batten as shown in Figure 3.1(a) and others failed by withdrawal from the rafter as shown in Figure 3.1(b). In the 45 mm batten test program, all fasteners failed by withdrawal.

3.1. 35 mm thick battens

Centrally located screws were installed either correctly driven (Data set 8) or overdriven (Data set 9), as shown in Figure 2.5. For this s

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	JD4		JD5	
Driven	All	Correctly driven	All	Correctly driven
Failure	All	[redacted]	All	All
Number	20	10	20	10

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As indicated in Section 2.5.2, correctly installed batten to rafter connections cannot satisfy the rafter edge distance requirements in Table 4.8 in AS1720.1 (Standards Australia 2010b). 10 connections were prepared with correctly driven fasteners installed non-centrally in rafters as shown in Figure 3.6. A range of rafter edge distances was selected.

Failure modes were all by withdrawal from the rafter. In some cases, the withdrawal was accompanied by splitting of the rafter as shown in Figure 3.6.

Figure 3.7 shows the 10 test results from the edge distance study as blue diamonds and the results from the correctly driven central test values as a blue ellipse. The design value from Table 3.3 is shown as a red line, and the blue line reflects the lower bound of the combined data sets for correctly driven screws through 35 mm battens. For most edge distances, the test data reflected a similar range to the central test data. However, at edge distances

3.2. 45 mm thick battens

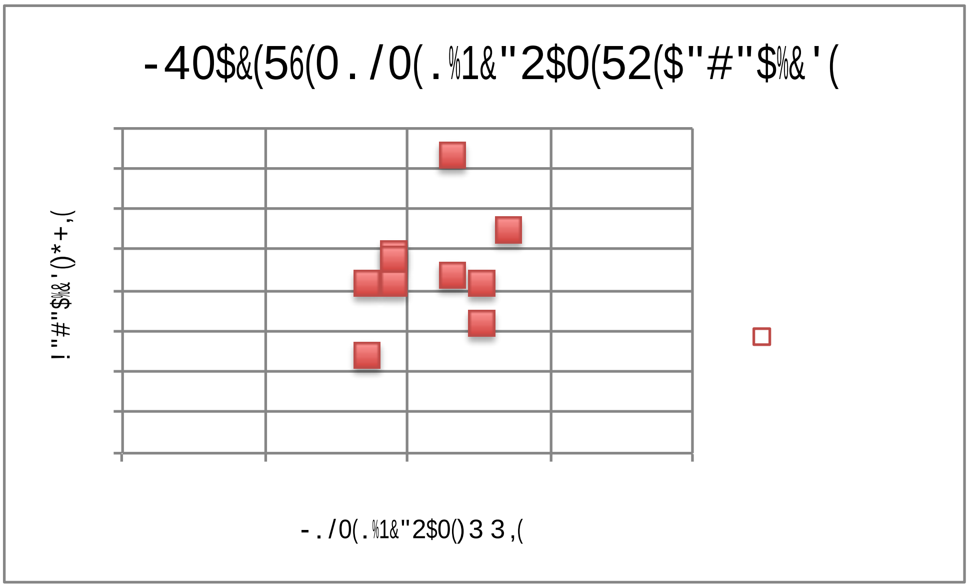
Each timber batten was connected to a MGP10 rafter by a single 75 mm long bugle head screw. Centrally located screws were installed either correctly driven (Data set 11 screws into 45 mm thick timber battens are not sensitive to differences in installation.

These trends can be seen in Figure 3.8.

Figure 3.9 shows that the capacity of screws through 45 mm thick battens at the 50%ile level is the same for all specimens at around 5.2 kN, regardless of how they were driven. This value divided by the depth of embedment gives 173 N/mm – almost identical to the 50%ile capacity of screws into 35 mm thick battens divided by its depth of embedment – 175 N/mm. The average of the characteristic values calculated using AS/NZS 4063.2 (Standards Australia 2010c) and ISO 12122.5 (International Standards Organisation 2015) was 3.56 kN for correctly driven fasteners, and 3.83 kN for the over-driven fasteners.

All of the failures were by withdrawal of the screws from the rafters; the withdrawal load could be related to the rafter density. T

	JD4		JD5	
Driven	All	Correctly driven	All	Correctly driven
Failure	All	All		



Tables 3.3 and 3.6 gave very similar results for the unit withdrawal capacity per mm depth of embedment for the tests in 35 mm thick battens (penetration 40 mm) and the tests in 45 mm thick battens (penetration 30 mm). These unit strengths were 119 N/mm and 113 N/mm respectively. Edge distance studies on the two battens were combined and shown in Figure 3.13.

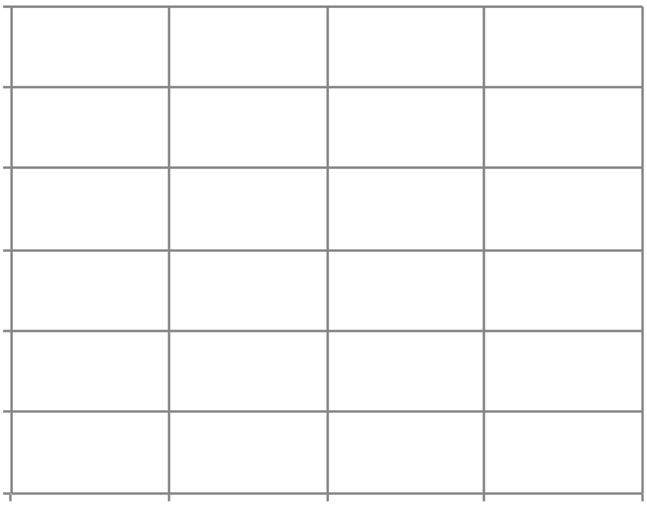


Figure 3.13 shows that the two different test programs gave very similar results and indicates +/- 5mm in tolerance for the positioning of the batten screw in the width of the batten.

4. TESTS ON METAL TOP-HAT BATTENS

Two series of tests were conducted on steel top-hat battens:

- Two M5.5–11x40 Batten Zip® screws, with a length of 40mm, as recommended by Lysaght for fixing steel battens to timber rafters (Lysaght 2014)
- Two 57mm length Ortons hot-dipped galvanised smooth shank nails with a round 5.5mm head and 2.56 mm diameter shank

4.1. Screws through top-hat battens

Each top-hat batten was connected to the MGP10 rafter by a pair of Batten Zip® screws – one on each side of the batten. The screws were installed either under-driven (Data set 1), correctly driven (Data set 2) or over-driven (Data set 3). Refer to Figure 2.6.

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Some fasteners failed by pull through in the batten as shown in Figure 4.1(a) and others failed by withdrawal from the rafter as shown in Figure 4.1(b).

Table 4.1 shows data for two Batten Zip® screws through top-hat battens and is illustrated in Figure 4.2.

Table 4.1 shows that for the batten to rafter connections:

- Most connections failed by pull-through rather than withdrawal;
- Over-driven connections had a significantly higher percentage of withdrawal

Figure 4.3 shows that:

- Most Batten Zip® screws that failed in withdrawal were over-driven;
- The strongest over-driven screws that failed in withdrawal had around the same capacity as the weakest of the over-driven screws that failed by pull-through;
- There was a significant difference between the capacity of the only under-driven screw that failed in withdrawal and the capacities of the over-driven screws that failed in withdrawal;
- The CFDs for the correctly driven and over-driven screws that failed by pull-through were similar. However, the CoV for the capacity of over-driven screws was much higher than the capacity of correctly driven screws because it was obtained from the total over-driven data shown in Figure 4.3(a) and (b).

Figure 4.4 indicates that there is almost no relationship between rafter density and strength of the fasteners that failed in withdrawal. Most of the withdrawal failures were for over-driven screws where over-driving damaged the fibres. The low capacity probably reflects the extent of the fibre damage rather than the inherent strength of the rafter

Section 2.1.1 showed that the average density of the rafters was within the range for JD4 timbers. Therefore the results of the tests applied to JD4 timber rafters.

An estimate of the strength of the same connections into JD5 timber rafters was calculated by scaling withdrawal loads by 0.8 (the ratio of JD5 withdrawal strength to JD4 withdrawal strength for screws in AS1720.1 (Standards Australia 2010b). The strength for any connections that failed by pull-through were not scaled as the mode of failure was independent of the density of the rafter; it was only affected by the

The significant difference at the 5%ile level between data for all connections and correctly driven connections highlights the sensitivity of the Batten Zip® screws to over-driving.

- There was a significant difference in characteristic values of capacity between the columns in Table 4.4. Batten to rafter connections using 57 mm nails into top-hat battens are sensitive to differences in installation.

Data set		**4**			**5**			**6**		
Driven	**All**	**Under-driven**			**Correctly driven**			**Over-driven**		
Failure	All	All	With-drawal	Pull-thru’	All	With-drawal	Pull-thru’	All	With-drawal	Pull-thru’
No.	50	11	6	5	18	11	7	21	12	9
Avg	2.50	2.82	2.60	3.09	2.72	2.44	3.17	2.15	1.99	2.36
Std dev	0.68	0.45	0.40	0.38	0.68	0.69	0.36	0.64	0.53	0.75
CoV	33%	16%	16%	12%	35%	39%	12%	32%	30%	34%
Max	3.75	3.50	3.17	3.50	3.75	3.06	3.75	3.44	2.66	3.44
Min	0.85	2.10	2.10	2.74	0.85	0.85	2.65	1.02	1.02	1.46
LN 5%ile	1.41	2.14	2.00	2.51	1.50	1.24	2.61	1.23	1.19	1.30

- There was a significant difference between the capacity of the over-driven nails that failed by pull-through and the capacities of the correctly and under-driven nails that failed by pull-through;
- The CFDs for the correctly driven and under-driven nails that failed in withdrawal were similar, except at the lower tail of the distribution;
- In general, over-driven nails had the lowest capacity for both withdrawal and pull-through failures – CFDs for over-driven nails are to the left of the correctly and under-driven nails in Figure 4.8(a) and (b).

Section 2.1.1 showed that the average density of the rafters was within the range for JD4 timbers. Therefore the results of the tests applied to JD4 timber rafters.

An estimate of the strength of the same connections into JD5 timber rafters was calculated by scaling withdrawal loads by 0.65 (the ratio of JD5 withdrawal strength to JD4 withdrawal strength for nails in AS1720.1 (Standards Australia 2010b). The strength for any connections that failed by pull-

	JD4		JD5	
Driven	All	Correctly driven	All	Correctly driven
Failure	All	All	All	All
Number	50	18	50	18
Average	2.50	2.72	2.04	2.20
Std dev	0.68	0.68	0.84	0.89
CoV	33%	35%	46%	50%
Maximum	3.75			

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Table 2.3 showed that during the preliminary study, it was found that two 57 mm hot-dipped galvanised coil nails were significantly stronger than two 75 smooth shank gun-driven nails in batten to rafter connections using top-hat battens.

The average capacity of two 57 mm hot-dipped galvanised nails was 1.45 times the average capacity of two 75 mm smooth shank nails. With similar Coefficient of Variation, the characteristic capacity of two smooth shank 75 mm nails anchoring top-hat battens to JD5 rafters was estimated at 0.50 kN.

4.3. Other connection configurations for top-hat battens

Testing was necessary to determine the characteristic capacity of the correctly driven fasteners limited by both withdrawal and pull through. Section 5 compares the test results with analytical withdrawal strength models in AS 1720.1 (Standards Australia 2010b). However, there are no analytical models to predict pull through capacity in metal batten flanges.

Other configurations of connections between top-hat battens and timber rafters will also need to be evaluated by rigorous testing programs. This is even more necessary if the connection is not symmetrical (e.g. a screw in only one flange, or a screw in one flange and a nail in the other). The lack of symmetry causes:

- moments on the whole connection;
- torsion in the batten; and
- prying forces

all of which may reduce pull through capacity of a single fastener.

These differences in behaviour mean that it will not be possible to extrapolate from the results published in this report for symmetrical connections to predict capacities for the same fasteners used in asymmetrical connections. However, the capacity of asymmetric connections using a screw in one flange of the batten is very likely to be less than half of the capacity of a connection using screws in each flange as determined in Section 4.1.

5. COMPARISON OF TEST CHARACTERISTIC VALUES WITH DESIGN VALUES

- The recommended Batten Zip® screws for top-

6. CONCLUSIONS

The testing and analysis program investigated four batten to MGP10 rafter connections that are commonly used under sheet metal roofing in Perth WA. AS 1684.2 (Standards Australia 2010a) includes connection capacities for one 75 mm long bugle head screw through 35 mm thick timber battens, but does not provide capacities for the other three connections tested in this study.

MGP10 timber can be either JD4 or JD5. The timber for the rafters used in this test program was JD4, but because some pieces of MGP10 supplied to the industry can be JD5, JD5 capacities are used in design. The models for connection capacity in AS 1720.1 (Standards Australia 2010b)

Mahendran M and Mahaarachchi, D (2002) “Cyclic pull-out strength of screwed connections in steel roof and wall cladding systems using thin steel battens