WCTE
WORLD CONFERENCE ON TIMBER ENGINEERING
2010

STRUCTURAL PERFORMANCE OF TIMBER EXTERNAL CLADDING

David Crawford[1]
Dr Robert Hairstans[2]
Ivor Davis[3]

ABSTRACT: Although timber cladding has been used for centuries, the current design guidance for timber cladding has received very little research attention with regards to structural performance. Due to the growing demand in several countries for medium rise timber facades it is imperative to ensure that connection detailing is robust in order to reduce any risk of failure. Timber facade design and detailing has to take into account the environmental conditions and the corresponding affect this has on durability, weathering, dimensional change and corrosion. This paper reports the initial findings of an extensive research programme investigating the impact of environmental exposure and the use of a range of commercially available preservative treatments on the structural robustness of timber cladding details. The experimental programme consists of comparing the structural performance of timber facade connection details constructed and tested in controlled environment conditions relative to those which have been placed in a 12 month data-logged exposure trial. Reported in this paper are the initial controlled environment withdrawal test results considering UK standard cladding details.

KEYWORDS: Cladding, Withdrawal, Headside Pull Through, Embedment.

1 INTRODUCTION

The environmental performance of timber is much greater in comparison to other building materials hence the current extended use for structural applications in the UK. Further to the load bearing elements of a build there is also a growing interest in the use of timber for building facades. Timber cladding is common place in Scandinavian countries but in the UK other materials such as masonry are more normally specified particularly for house construction. The use of timber as cladding is beneficial as it is a more sustainable product if appropriately sourced and can be more readily installed in the factory. However, there is limited available structural specification information and recently this has been highlighted particularly in Scotland due to the new Structural Engineers Registration (SER) legislative requirements. SER requires the structural engineer to take overall responsibility of the building envelope through the building certification process. Therefore, the engineer is also responsible for ensuring that the cladding specified will be robust in service conditions.

2 PROJECT BACKGROUND

To produce cladding logs are machined and cut into boards and this uses minimum energy input relative to other cladding alternatives. Transportation, drying, preservation treatments, machining, coating and maintaining any finishes are all aspects that can also affect the total energy consumption. However, careful selection and specification of timber cladding can minimise both these short and long term effects.

By and large timber cladding is softwood, which can be readily obtained from the expanding coniferous forests worldwide. Softwoods such as western red cedar and European larch or Douglas fir are generally chosen for their natural durability; however, it is equally suitable to treat less durable woods, such as European redwood or whitewood with preservatives in order to increase their durability. It is worth noting though that some preservative treatments have been found to be highly corrosive to the fixings employed thus affecting the performance of the connection. Therefore, care requires to be taken during the design and detailing process in order to ensure the safe specification of preservatives.

[1] David Crawford, Edinburgh Napier University, School of Engineering and the Built Environment, Merchiston Campus, 10 Colinton Road, Edinburgh, EH10 5DT. Email: d.crawford@napier.ac.uk
[2]Robert Hairstans, Edinburgh Napier University, Email: r.hairstans@napier.ac.uk
[3]Ivor Davis, Edinburgh Napier University, Email: ivor@greenporch.demon.co.uk

In order to gain a full understanding of the affects of climatic conditions and preservative treatment on structural performance of cladding connections an on-going investigation is being undertaken by Edinburgh Napier University. The basis of the project is to compare the results from the structural testing of European Standard cladding connection details with those calculated from European structural design code of practice. The results from this programme of work are to be disseminated to engineers in order to ensure safe cladding specification. As well as being of practical benefit to façade designers, this study will also help improve timber's competitiveness relative to other façade materials.

3 SITE PRACTICE & DETAILING

Probably the most common layout of timber cladding is to fix the timber horizontally to the building (Figure 1). Finished boards can either be a simple overlap design, feather or square edged, or if a flush surface is require a rebated feather edge or shiplap may be used. Open jointed boards may also be used where the top and bottom edges of the board are chamfered, in order to let the rain water run to the outside and provide some overlap.

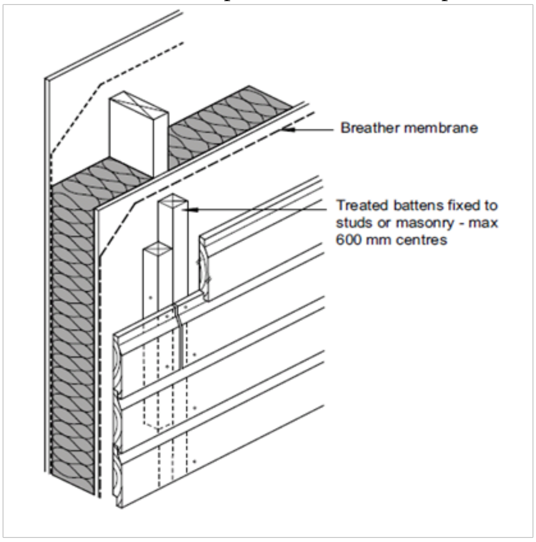

Figure 1 *Horizontal cladding boards* **(3)**

Another common layout is vertical timber cladding (Figure 2) which is connected together using a tongue and groove system. However, board widths should be limited when using tongue and groove in order to ensure moisture movement does not consequently disengage the tongues. In order to avoid this from occurring rebated boards should be specified as this provides a flush surface and an adequate overlap to allow for shrinkage. Vertical boards with open joints on battens can be used but more rainwater will penetrate the joints thus increasing the risk of corrosion. Another form of vertical cladding is board on board, which consists of an inner layer of boards spaced apart over which an outer layer is then fixed to cover the gap between the inner layers. Adequate overlap must always be provided to allow for any shrinkage of the boards due to fluctuation of moisture. An advantage of board on board cladding is that between the batten which the cladding is fixed to and the outer layer of cladding there is a small gap which provides ventilation and drainage to the cavity. When using vertical cladding consideration should be taken as the lengths of timber which are to be used. End to end joints are crucial as there is a high risk of swelling if rain gets into the end grain of the timber.

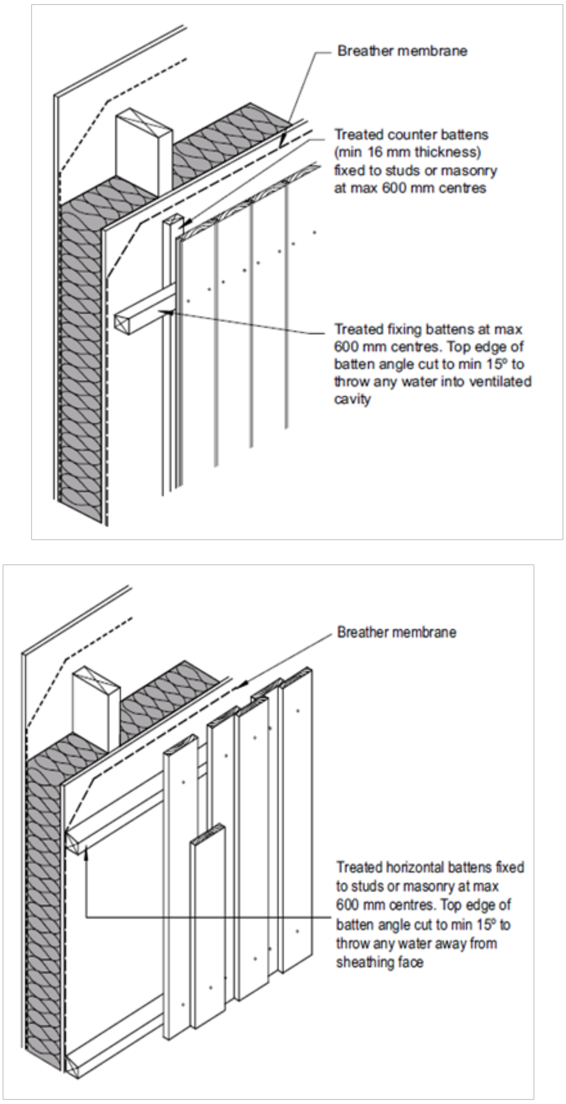

Figure 2 *Vertical cladding boards* **(3)**

4 SPECIFICATION

4.1 General Information

Battens used for cladding should be preservative treated and structurally graded to ensure they are able to carry the weight of the board material. When fixing horizontal boards to vertical battens, care should be taken where boards are jointed to ensure they sit securely on sufficient batten width. When fixing vertical board's to horizontal battens, vertical 'counter' battens should be employed to facilitate drainage and ventilation. Support battens should be fixed at spacing's of no more than 600mm, whether vertical or horizontal, and at no more than 400mm for diagonal boards. These spacing's will help maintain the overall stability of the cladding. It is also worth noting that edge spacing of fixings should conform with Eurocode edge and end distance requirements.

4.2 Moisture Movement

Due to environmental conditions in the UK there is a high variation in the moisture content of externally exposed timber, and as the cells of wood fibres shrink or expand when they lose or gain moisture there is a good chance some degree of movement will occur. Depending on which direction the external timber cladding is facing the moisture content may vary between 22% - 10%. Seasonal variation on any one face does not tend to vary much between 6% and 8%; however, this is ample to cause swelling and shrinkage of the wood. Although this does not directly affect the strength or durability of the timber, it may consequently lead to splitting, cupping or bowing if the fixings do not allow for movement. In order to reduce the risk of movement it is suggested by BS EN 1186-3 (1) that timber cladding in the UK should be erected as close to the "in use" moisture content as possible which is between 13% and 19%. Movement can be further reduced by limiting the width of the boards, and if possible, the heartwood side of the board should be used as the external face of the cladding to make sure joints remain tight.

4.3 Timber protection

BS 8417 (2) Preservation of timber Recommendations, provides guidance on the treatment of timber for use in the UK, and refers to other crucial parts of relevant BS and BS EN documents. BS 8417 gives an overview of service factors based on safety and economic considerations which have been developed in the standards framework. From this a service life of up to 60 years may be specified, however, whether this is attained with the use of preservatives or by selecting a naturally durable timber is down to the durability requirements and the designer.

Since the publication of BS 8417, some of the preservatives such as Chromate Copper Arsenate are no longer approved and others have taken its place. The Wood Protection Association Manual 'Industrial wood preservation specification and practise' contains an overview on selection, specification and recommendations for treatment of timber products, including cladding, along with details of current preservative product names and suppliers.

Generally pressure and double vacuum treatments are the most effective way to apply preservative treatments, however, other immersion or pressure and vacuum methods are used. When using unfinished timber it is advised that, water-borne copper organic treatments are used, although these may tend to leave a greenish tinge to the wood which will only fade with time. This preservative must be fully dried before the wood is handled.

If the cladding is to be finished using a protective treatment i.e. paint or stain, light organic solvent preservatives are generally used, also applied by using vacuum and pressure or immersion methods. Due to the spirit based nature, organic solvent treatments do not lead to an increase in the moisture content of the wood, hence the risk of distortion of profiled sections is reduced. This treatment should also be fully dried before the wood is handled.

An alternative is to use boron salts as a preservative, however this treatment is only appropriate for 30 year service life, even when used in conjunction with a protective surface coating. Boron salts are soluble in water and hence are vulnerable to leaching, due to this, the timber should be protected by a surface coating system.

4.4 Connection Detailing

The overall performance of timber cladding relies heavily on the connection detail; in order to ensure the robust performance of timber cladding a range of factors should be considered during the specification process. These include species type, size and length of the boards, the degree of weather protection, durability, ease of erection, fixing methods and choice of finish i.e. preservative treatments/coatings. The following guidance is provided when fixing external softwood and hardwood cladding:

Softwood

- Annular ring shank nails are recommended for fixing softwood cladding.
- The nail length is generally twice the thickness of the board being fixed and should be punched slightly below the wood's surface
- Boards over 100mm wide should have double fixings
- Make sure that butt joints always meet on sufficient batten support width
- It's essential to use stainless steel nails for species with high tannin content and for timbers installed 'green'. This avoids permanent staining due to the reaction on mild steel or galvanised nails. (3)

Hardwood

- Screws are the preferred method of fixing for hardwood boards. Stainless steel screws are preferable, and essential for timbers installed 'green':
- Slight over-drilling of the screw holes will allow for any movement in the wood and prevent splits. Countersinking screws is also recommended
- Where 'green' wood is used, it may be necessary to fit washers to the screws to maintain the fixing security. This can become a design feature
- Metal clips, which also provide a 'secret fix' effect, may also be considered. Screw fixings should be at least 40mm from the end of the boards to avoid splitting. (3)

The above guidance has to be considered relative to the in-situ conditions and with respect to this there are a range of dowel type fasteners available varying in diameter, length and composition available and used in practice to fix cladding in position.

5 EXPERIMENTAL INVESTIGATION OF WITHDRAWAL STRENGTH

Withdrawal strength of the fixing is an important factor when considering cladding and is often the limiting design criteria as a result of wind suction. In the UK low velocity shot fired nails is the preferred method employed to fix cladding due to their ease and speed of application. However, these offer relatively low withdrawal strength in comparison to that of a screw.

In accordance with BS EN 1995-1-1:2004 (4) the withdrawal capacity of an axially loaded nail is the minimum of pointside withdrawal or headside pull through. Considering this a test programme was set up to provide withdrawal capacity guidance for UK industry standard details considering Scots pine cladding as the facade material:

- Connecting counter batten to vertical batten and timber frame: Pointside withdrawal of 3.1x90mm smooth shank nail from 25x50mm vertical timber batten, 9mm OSB/3 and 45x145mm timber stud & headside pull-through 38x50mm counter timber batten.
- Connecting timber cladding to counter batten: Pointside withdrawal of 2.65x60mm annular ring shank nail from 38.5mm penetration into a timber cross batten & headside pull-through 21.5x120mm Scots pine cladding (Figure 3).

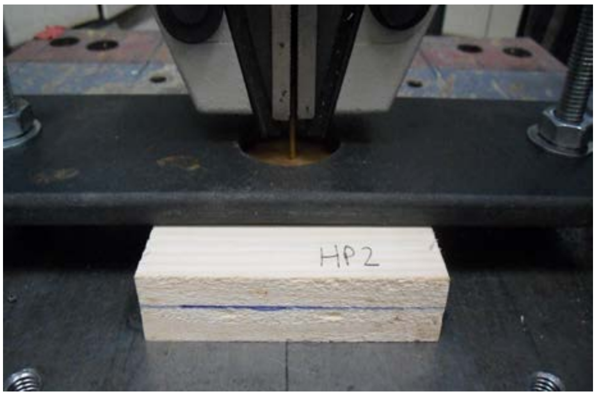

***Figure 3** Pull through scots pine cladding test*

It is worth noting that the headside pull through calculation procedure in BS EN 1995 is based on the nail head diameter. According BS EN 10230-1 (5) the nail head diameter can be calculated as 2.25 × diameter of the nail shank. However, the nail head of the 3.1x90mm smooth shank nail is non-standard (Figure 4).

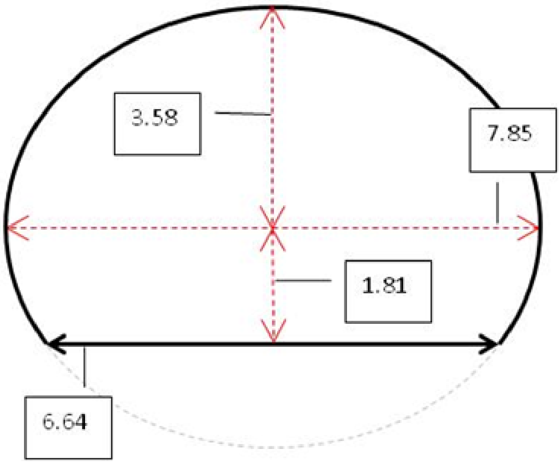

***Figure 4** Nail head of 3.1x90mm smooth shank nail*

The results of the test program are presented in Figure *5* to Figure 7 and compared relative to BS EN 1995 calculated values. All calculated results have been carried out in accordance with BS EN 1995 using the actual characteristic densities of the timber samples used in test (Table 1). The headside pull through of the 3.1x90mm smooth shank nail has been calculated based on both BS EN 10230-1 and an equivalent diameter. The equivalent diameter has been interpolated from the actual headside area of the fixing.

***Table 1:** Characteristic density of timber cladding detail components*

Material	Characteristic
	kg/m^3
Timber vertical batten	417.86
OSB/3	631.10
C16 Stud	372.59
Timber counter batten[1]	389.57
Timber counter batten[2]	359.53
21.5x120mm Scots pine cladding.	452.91

Note:
1. Connecting counter batten to vertical batten and timber frame detail
2. Connecting timber cladding to counter batten detail

The test results demonstrate that BS EN 1995 is relatively conservative for the cladding connections tested which is expected. The use of the results presented in design would require to be suitably factored to account for load duration and moisture content conditions.

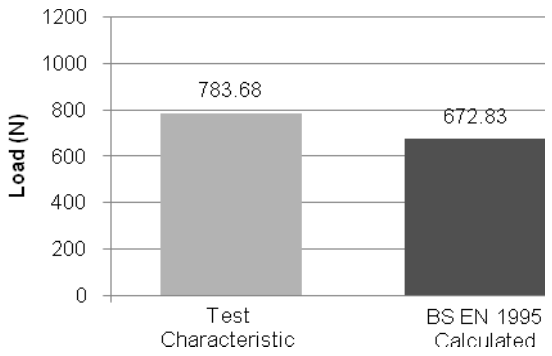

Figure 5 *Characteristic p*ointside withdrawal of 3.1x90mm smooth shank nail from 25x50mm vertical timber batten, 9mm OSB and 45x145mm timber stud

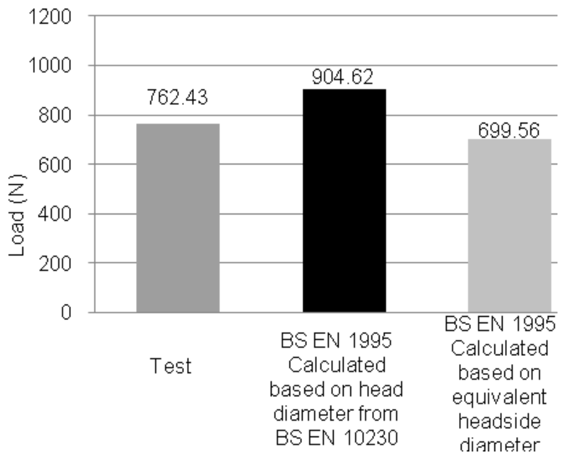

Figure 6 *Characteristic headside pull through of 3.1x90mm smooth shank nail through 38x50mm counter timber batten*

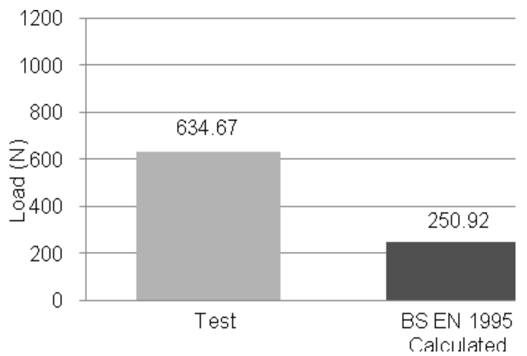

Figure 7 *Characteristic pointside withdrawal of 2.65x60mm annular shank nail from 38.5mm penetration into a timber cross batten*

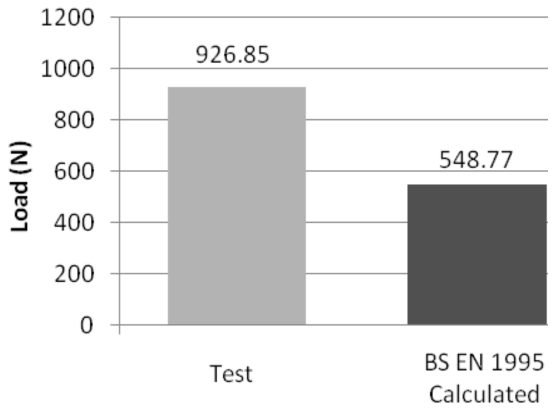

Figure 8 *Characteristic headside pull through of 2.65x60mm annular shank nail through 21.5x120mm Scots pine cladding*

Note: Headside withdrawal has been calculated in accordance with BS EN 1995-1-1:2004+A1:2008 equation 8.24 for 'smooth nails' as it was considered that taking into account the frictional resistance of the shank pulling through the timber in combination with the headside pull through strength was more representative.

6 CONCLUSIONS

As previously stated the withdrawal capacity of an axially loaded nail is the minimum of pointside withdrawal or headside pull through. For the UK standard construction detail considered in this experimental investigation it is demonstrated that when considering wind suction on the face of a building the critical parameter would be pointside withdrawal of the annular rink shank fixing connecting the external cladding to the timber cross batten.

Considering the results presented in Figures 5to 8 BS EN 1995, for the majority of cases, provides an underestimation of the actual withdrawal or headside pull through of the connection, with the exception of the headside pull through of the 3.1×90mm nail from the 38×50mm counter batten. However, the method of determining headside pull through in accordance with BS EN 1995 and BS EN 10230 based on the headside diameter of the fixing does not take account of the deformed shape of the nail head. Taking the deformed shape head of the nail head into consideration and carrying out the calculation using an equivalent nail head diameter based on the actual cross sectional area is demonstrated to be more appropriate (Figure 6).

The results reported in this paper for withdrawal capacity require to be design factored in order to take into account the effects of climatic conditions and preservative treatments on strength. It is also recommended that further testing be carried out on a range of commercially available fasteners as to attain more accurate values in the case of deformed nails including head and shank detailing.

7 FURTHER WORK

The work reported in this paper is on-going and a 12 month experimental exposure trial is currently underway which consists of a range samples treated with different types of preservatives and placed at two separate locations in the Scottish Highlands.

Figure 9 *Exposure site – Fort William, Scotland.*

From this a direct comparison will be made between the structural performance of the connection details tested in controlled environment conditions relative to those which have been placed at an exposure trial. The samples placed at the exposure trial are being monitored for moisture movement fluctuations using pre-installed moisture sensors and data-loggers.

8 REFERENCES

1. **BS EN 1186-3:1190** - *Timber for and workmanship in joinery - Part 3: Specification for wood trim and its fixing.* s.l. : BSI.
2. **BS EN 8417:2003** - *Preservation of timber - Recommendations.* s.l. : BSI.
3. **Hislop, Paddy.** *External timber cladding 2nd Edition.* Buckinghamshire : Trada Technology Ltd, 2007. ISBN: 978-1-9000510-55-4.
4. **BS EN 1995-1-1** - *Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings.* s.l. : BSI.
5. **BS EN 10230-1-** *Steel wire nails - Part 1: Loose nails for general applications.* s.l. : BSI.
6. **I. Davies, B.Walker, J.Peendlebury.** *Timber Cladding in Scotland.* Edinburgh : ARCA Publication Ltd., 2002. ISBN - 1904320 007.
8. **H.J. BLASS, B.O. Hilson.** *Timber Engineering Step-1 - Basis of Design, Material Properties, Structural Components and Joints.* Netherlands : Centrum Hout, 1995.
9. **Kermani, J. Porteous & A.** *Structural Timber Design to Eurocode 5.* Edinburgh : Blackwell Science Ltd, 2007. ISBN: 978-14051-4683-8.