Embedding and withdrawal resistance of screws on thermal treated wood

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ABSTRACT

Tests were conducted at LNEC to assess withdrawal resistance and embedding strength of commercial heat treated wood (ThermoWood®) Thermo-D pine with various types of screws, to predict the short-term performance of screwed joints. These had in mind a suitable design and detailing of screwed joints in ThermoWood®, even in non-structural applications, where the wood components have to fulfil certain strength requirements and their assembly and fixings have to be strong enough to assure long-term performance and durability. Test results were analysed as a function of the material density, and compared to non-modified wood, in the light of common joint design principles. This work contributes to debate the suitability of using the equations given by Eurocode 5 (EN 1995-1-1:2004/A1, 2008) to the design of screwed joints in non-structural ThermoWood®.

INTRODUCTION

Wood modification has been carried out for several decades as an attempt to improve certain wood characteristics like durability and dimensional stability.

Amongst the modified wood products that have reached the commercial stage, heat treated wood is perhaps the most common. However, the various heat treatments available are known to strongly reduce wood mechanical properties, namely by increasing brittleness, therefore restraining the use of heat treated wood to non-structural applications, like exterior decks and wall linings.

Even in non-structural applications, the wood components have to fulfil certain strength requirements and their assembly and fixings have to be strong enough to assure long-term performance and durability. One less studied aspect concerning the modified wood products is their ability to retain metal fasteners and the corresponding performance of joints.

Therefore an experimental program was conducted at LNEC to assess withdrawal resistance and embedding strength of commercial heat treated wood (ThermoWood®) Thermo-D pine with various types of screws.

EXPERIMENTAL PROGRAM

Embedding strength

Tests were conducted on European redwood (*Pinus silvestris* L.), spruce (*Picea abies* H. Karsten) and ThermoWood® loaded parallel to the grain. For each one of these materials, sampling aimed to cover the widest possible range of density values. The

following screws were used without predrilling: WT-T4.5 (4.5 mm x 60 mm) and WT-T6.5 (6.5 mm x 65 mm) from SFSintec.
Timber was conditioned at 20 ºC/65% until stabilisation, attaining the following average moisture content: 6.1% (ThermoWood®), 12.6% (redwood) and 13.2% (spruce).
Test specimen sizes and test procedures were in general accordance with EN 383 (2007); although specimen thickness was 20% higher than the maximum established in the standard, screws showed no deformation after tests, as required. Care was taken to ensure that the timber was loaded by the threaded part of the screw only.

Withdrawal resistance

Tests were conducted on spruce and ThermoWood®. Besides screws WT-T4.5 (4.5mm x 60mm) that are currently used to fix ThermoWood®, also common screws 5.0mm x 60mm were tested. These had similar internal diameters (Figure 1), and in both cases were driven without predrilling.

Figure 1:** **a) Common screw 5.0x60 (d_{ext}=5.0 mm; d_{int}=3.1 mm), b) SFSintec WT-T4,5 (d_{ext}=4.5mm; d_{int}=3.3 mm)

The length of the threaded point of WT-T4.5 screw is 22.5 mm. Therefore, this was adopted as the anchorage length for all tests, since the recommended values of $8d_{int}$ (EN 1382: 1999) and $6d_{ext}$ (EN 1995-1-1:2004/A1, 2008) would imply that the anchored length would also include some part of the smooth shank. Test specimens were 42mm x 42mm (direction parallel to the screw) x 100mm (fibres direction), and were conditioned at 20 ºC/65%HR, to constant mass prior to tests.
Tests followed EN 1382 (1999).

RESULTS AND DISCUSSION

Embedding strength

Figure 2 presents embedding strength results, calculated from the maximum load attained up to the maximum displacement of 5mm, divided by the specimen thickness and the effective screw diameter d_{ef}, taken as $d=d_{smooth}$. It also presents the correlation with density proposed by EN1995-1-1 (2004, 2008), for small nails and screws loaded parallel to grain ($d \leq 6$mm): $f_h = 0.082\ \rho\ d^{-0.3}$.
In the case of WT-T4.5, $d=d_{smooth}$=3.3mm (where d_{smooth} is the diameter of the smooth part of the shank). The following coefficients of determination were obtained: R^2=0.72 for ThermoWood®; R^2=0.91 for redwood and R^2=0.69 for spruce.
In the case of WT-T6.5, $d=d_{smooth}$=4.5mm. Coefficients of determination are: R^2=0.86 for ThermoWood®; R^2=0.86 for redwood and R^2=0.70 for spruce.
The good agreement of embedment test data with Eurocode 5 expressions in the case of natural redwood and spruce, in spite of specimen thicknesses slightly exceeding the limits of EN 383 (2007), validate these tests.

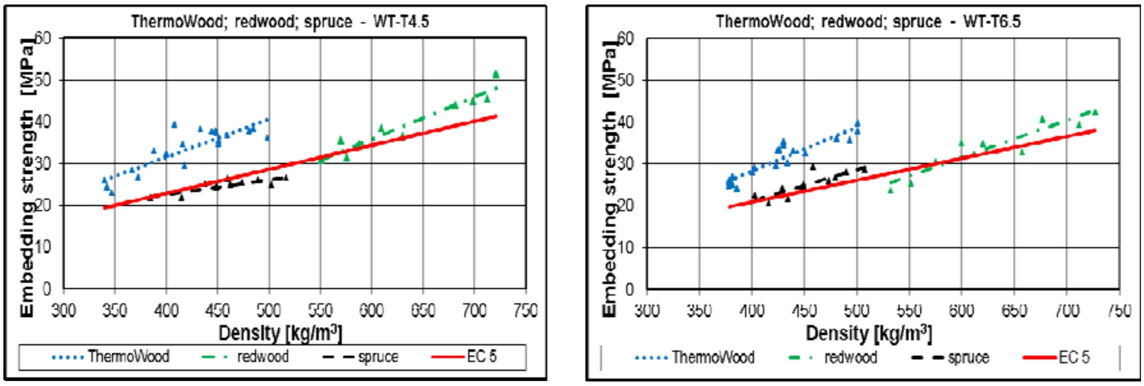

Figure 2: Embedding strength of ThermoWood®, redwood and spruce: a) WT-T4.5; b) WT-T6.5

Withdrawal resistance

Figure 3 presents the maximum withdrawal load $F_{Máx}$ obtained for ThermoWood® and the corresponding regression lines with density, in the case of WT-T4.5 (R^2=0.78) and common screws 5.0mm x 60mm (R^2=0.75).

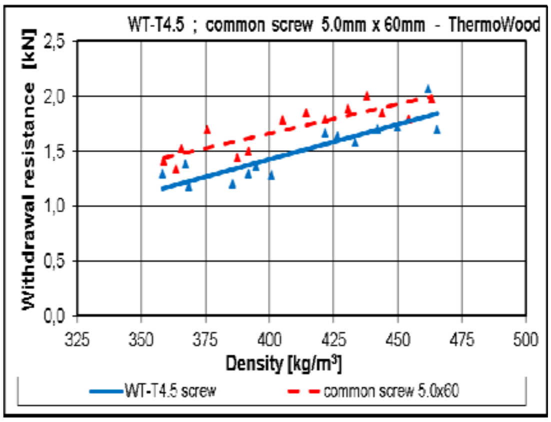

Figure 3: Withdrawal resistance for ThermoWood® with WT-T4.5 and common 5.0mm x 60mm screws

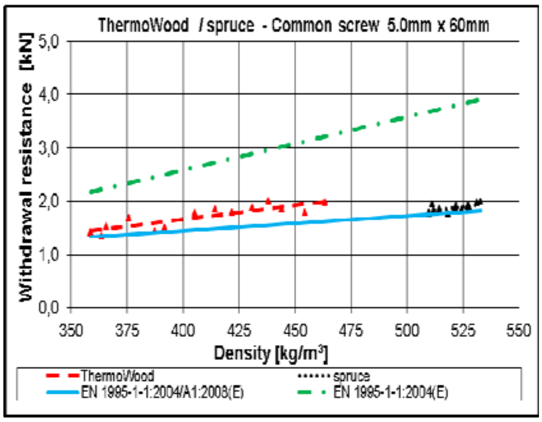

Figure 4: Withdrawal resistance for ThermoWood® and spruce with common 5.0mm x 60mm screws

Figure 4 presents the maximum withdrawal resistance $F_{Máx}$ obtained for common screws 5.0mm x 60mm and the corresponding regression lines with density, in the case of ThermoWood® (R^2=0.75) and spruce (R^2=0.34).

It also presents the correlation with density proposed by EN 1995-1-1:2004/A1 (2008) to the withdrawal resistance of a screw loaded perpendicular to the wood fibres (α=90º), assuming that the equation (1) proposed to characteristic values of strength and density is also valid here:

$$F_{ax,k,Rk} = 0.52\ \rho^{0.8}\ d_{ext}^{0.5}\ l_{ef}^{0.9}\ \ k_d\ /\ (\text{sen}^2\alpha + 1.2\cos^2\alpha) \qquad (1)$$

Where:

d_{ext} – external diameter of the thread of the screw (5.0mm)

l_{ef} – effective anchorage length ($l_{ef} = l_{anch} - d_{ext}$ = 22.5 – 5.0 = 17.5mm)

k_d = min (1, d_{ext}/8)

α = 90º = angle between load and wood fibres; ρ – density

Figure 4 presents also the expression given by EN 1995-1-1 (2004), to evidence the major correction introduced to Eurocode 5 by Adenda 1 of 2008 relating to this topic. Although the particular geometry of SFSintec screws (with a smooth central length) imposed a too small anchorage length for all withdrawal tests (22.5mm) as compared to standards specifications, tests data obtained for spruce shows good adjustment to Eurocode 5 equations (version of 2008), thus validating these tests.

CONCLUSIONS

It was shown that embedding strength of ThermoWood® increases with its density similarly to what happens with non-modified (natural) wood. Furthermore, equations given by Eurocode 5 for the embedment strength agree well with test results obtained with natural spruce and redwood, but underestimate the embedding strength of ThermoWood®. Despite the general trend for strength decrease due to the heat treatment, it should be mentioned that former studies (Widmann 2008, Shi *et al*. 2007) showed that some mechanical properties, as hardness and compression parallel to the grain, of heat treated wood may be higher than the corresponding ones of non-modified wood of the same species, although the influence of treatment vary with wood species. Regarding withdrawal tests, results evidenced similar withdrawal resistance of ThermoWood® and spruce, both being in good agreement with EN 1995-1-1:2004/A1 (2008) equations.

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