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Wood Fibre Insulation Boards as Load-Carrying Sheathing Material of Wall Panels

Gunnar Gebhardt[1], Hans Joachim Blaß[2]

ABSTRACT: To date wood fibre insulation boards (WFIB) are used as thermal and acoustic insulation in timber construction. As wood-based panels, WFIB are also suited for the transfer of loads caused by wind and earthquakes in timber frame construction, where they may replace plywood, particle boards or OSB. This new field of application of WFIB has been analysed in a research project at Karlsruhe Institute of Technology.
In order to calculate the load-carrying capacity of wall and roof panels the characteristics of WFIB as well as those of joints with WFIB and dowel-type fasteners need to be known. In tests these characteristics were determined. A proposal is made for the calculation of timber-WFIB-joints with dowel type fasteners. Furthermore the stiffness properties of timber-WFIB-joints were determined. In this paper the results of the tests are presented.

KEYWORDS: Wood fibre insulation board, wall panel, sheathing material

INTRODUCTION AND CHARACTERISTICS OF WFIB

Wood-based sheathing materials in timber frame construction normally are plywood, particle boards or OSB. A further possibility is sheathing made of gypsum plasterboards. These panels have a relatively high density caused by the compression and adhesion of the different raw materials. The heat insulation properties do not equal those of typical insulation materials like mineral or wood fibre. For the heat insulation of outer walls therefore additional insulation material is required. Due to the increasing demands regarding energy and CO_2 saving the insulation thickness increases. Wood fibre insulation materials produced as panels are therefore suited for the use in shear walls in timber frame construction if they are able to carry the shear loads in the panel itself and if the connections between WFIB and timber members have a sufficient strength and stiffness. This new field of application of WFIB was analysed in a research project at Karlsruhe Institute of Technology. In this paper a proposal is given to calculate the load-carrying capacity of timber-WFIB-joints with dowel-type fasteners. For this purpose the load-carrying capacity of joints in timber and WFIB is determined according to Johansen's yield theory and an extension of this theory. Tests were carried out to evaluate the embedding strength of nails in WFIB and the crown pull-through resistance of wide-crown staples in WFIB. The test results verified the calculation model and the stiffness properties of timber-WFIB-joints were evaluated. Furthermore the shear strength and the shear modulus of WFIB were determined.

The raw material of WFIB is wood chips. WFIB are fabricated in two different manufacturing processes. In both the wood chips are first thermo-mechanically pulped. In the wet process the wood fibres are mixed with water and further aggregate into a suspension. Afterwards the boards are formed and dried. For the bonding of the wood fibres only the wood´s own cohesiveness (predominantly lignin resin) is used. Due to the high use of energy for the drying process, boards with higher thicknesses are manufactured by gluing raw single-layer boards to multilayer boards, where also different density boards may be combined. In the dry process the wood fibres are dried and sprayed with resin. Afterwards the boards are formed and the resin hardens. In this process boards with thicknesses up to 240 mm are manufactured as single-ply boards. WFIB are used in different parts of buildings. In roofs, rain-tight sub plates are fixed as sub decking. A further insulation is possible as above-rafter or interim-rafter insulation with universal insulation boards. In walls, plaster baseboards may be used in composite thermal insulation systems. 11 different WFIB of three different manufacturers were selected to analyse the characteristics needed for the use as sheathing in shear walls. The nominal density range was between 110 kg/m^3 and 270 kg/m^3. The densities and moisture contents of the tested boards were determined. The measured moisture content was 7.3% to 10.3%.

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ANALYSIS OF WALL PANELS

In analysis methods the load-carrying capacity of the connection between timber member and sheathing panel is required. The analysis according to German design code DIN 1052 in addition requires the shear strength of the sheathing panel. The connection's load-carrying capacity is calculated according to Johansen's yield theory considering the different failure mechanisms.

In joints with fasteners driven in through a counter batten the inclination of the fastener in failure modes 1a and 2b involves embedding resistances in the counter batten. Hence the related equations for these failure mechanisms are extended. The load path is from the stud into the sheathing panel. There is no resulting load in the counter batten. Force and moment equilibrium, considering the existing embedding strength distribution and the yield moment, result in equations for the extended failure mode 1a and for the extended failure mode 2b.

The load-carrying capacity increases with increasing axial load-carrying capacity of the fastener. If the fastener is driven in directly into the sheathing panel the axial load-carrying capacity depends on the withdrawal parameter of the fastener in the timber member and the head/crown pull-through resistance in the sheathing panel or a counter batten, if the fastener is driven in through a counter batten

BASIC PARAMETERS OF DOWEL-TYPE FASTENERS IN WFIB

About 600 embedment tests with nails were performed according to EN 383 in order to evaluate the embedding strength of dowel-type fasteners in WFIB. The test results for the embedding strength correlate with the measured densities of the test specimens and the fastener diameter. By means of a multiple regression analysis an equation was derived for the embedding strength of WFIB. In order to calculate the rope effect the crown pull-through resistance of wide-crown staples in WFIB was examined. According to EN 1383 about 100 tests with RTSP and PB were carried out. The displacement at maximum load correlates with the thickness of the WFIB. By means of a multiple regression analysis an equation was derived to estimate the crown pull-through resistance of staples in WFIB.

LOAD-CARRYING CAPACITY AND STIFFNESS OF TIMBER-WFIB-JOINTS

In order to verify the results obtained in tests and to examine the stiffness of joints, further tests were performed. In tests with joints the calculated values considering the determined parameters are checked. Furthermore the stiffness of timber-WFIB-joints was evaluated. Rain-tight sub plates of three manufacturers in three thicknesses, respectively, and plaster baseboards were used as sheathing panel. Nails and staples were driven in through a counter batten. Wide-crown staples were driven in directly.

The load-carrying capacity may be obtained according to Johansen's yield theory considering the test results and the extended calculation model. The yield moments of the fasteners were evaluated according to EN 409. The embedding strength of staples in WFIB was calculated assuming the validity for diameters smaller than the tested ones. The embedding strength of nails in WFIB was determined in tests and used for the calculation. The embedding strength of the fastener in the timber member was calculated according to DIN 1052 considering the specimen densities. The withdrawal resistance and the pull-through resistance were calculated according to DIN 1052 for nails and staples. The crown pull-through resistance for wide-crown staples was determined in tests.

The tests were carried out according to EN 26891. The maximum load was reached at a displacement of 15 mm. Although failure mode 1b was governing in the calculation for nails, failure mode 3 was observed in the tests. This may be explained by friction between the joint members. The relative deformations between WFIB and stud were measured at each of the four fasteners. The analysis of the joint stiffness considers a linear load-displacement behaviour up to 40% of the maximum load. Due to a non-linear load-displacement behaviour the analysis of the stiffness was calculated for a constant displacement of 0.3 mm. By means of a multiple regression analysis an equation was derived to calculate the stiffness of timber-WFIB-joints.

SHEAR STRENGTH AND SHEAR MODULUS OF WFIB

The shear strength and the shear modulus of WFIB were determined according to EN 789. The WFIB specimens were reinforced by four lateral timber boards connected with the WFIB test specimen by five pre-stressed bolts. The correlation between shear strength, density and board thickness was analysed. The correlation coefficient between shear strength and board thickness is $r = -0.544$, while the correlation coefficient between shear strength and density is $r = 0.847$ and between density and board thickness is $r = -0.429$.

Furthermore the correlation coefficient between shear modulus and density is $r = 0.894$.

CONCLUSIONS

To date wood fibre insulation boards are used as acoustic and thermal insulation. As wood-based panels they can also be used for the load transfer in wall panels. The load transfer requires a sufficient load-carrying capacity of the joint between studs and sheathing and sufficient shear strength of the WFIB. In order to calculate the load carrying capacity of joints between timber and WFIB the embedding strength of nails in WFIB and the crown pull-through resistance of wide-crown staples in WFIB were determined. Johansen's yield theory was extended to consider the influence of a counter batten on the load carrying capacity. The stiffness of joints between timber and WFIB was evaluated in further tests. The shear strength and shear modulus of WFIB were also determined in tests. The results serve as a basis for the analysis of wood fibre insulation boards as sheathing panel in timber frame construction.

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In order to calculate the load-carrying capacity of wall and roof panels the characteristics of WFIB as well as those of joints with WFIB and dowel-type fasteners need to be known. In tests these characteristics were determined. A proposal is made for the calculation of timber-WFIB-joints with dowel type fasteners. Furthermore the stiffness properties of timber-WFIB-joints were determined. In this paper the results of the tests are presented.

KEYWORDS: Wood fibre insulation board, wall panel, sheathing material

1 INTRODUCTION

Wood-based sheathing materials in timber frame construction normally are plywood, particle boards or OSB. A further possibility is sheathing made of gypsum plasterboards. These panels have a relatively high density caused by the compression and adhesion of the different raw materials. The heat insulation properties do not equal those of typical insulation materials like mineral or wood fibre. For the heat insulation of outer walls therefore additional insulation material is required. Due to the increasing demands regarding energy and CO_2 saving the insulation thickness increases. Wood fibre insulation materials produced as panels are therefore suited for the use in shear walls in timber frame construction if they are able to carry the shear loads in the panel itself and if the connections between WFIB and timber members have a sufficient strength and stiffness. This new field of application of WFIB was analysed in a research project at Karlsruhe Institute of Technology.

In this paper a proposal is given to calculate the load-carrying capacity of timber-WFIB-joints with dowel type fasteners. For this purpose the load-carrying capacity of joints in timber and WFIB is determined according to Johansen's yield theory and an extension of this theory. Tests were carried out to evaluate the embedding strength of nails in WFIB and the crown pull-through resistance of wide-crown staples in WFIB. The test results verified the calculation model and the stiffness properties of timber-WFIB-joints were evaluated. Furthermore the shear strength and the shear modulus of WFIB were determined.

2 CHARACTERISTICS OF WFIB

The raw material of WFIB is wood chips. WFIB are fabricated in two different manufacturing processes. In both the wood chips are first thermo-mechanically pulped.

In the wet process the wood fibres are mixed with water and further aggregate into a suspension. Afterwards the boards are formed and dried. For the bonding of the wood fibres only the wood's own cohesiveness (predominantly lignin resin) is used. Due to the high use of energy for the drying process, boards with higher thicknesses are manufactured by gluing raw single-layer boards to multilayer boards (figure 2), where also different density boards may be combined.

In the dry process the wood fibres are dried and sprayed with resin. Afterwards the boards are formed and the resin hardens. In this process boards with thicknesses up to 240 mm are manufactured as single-ply boards (see figure 1).

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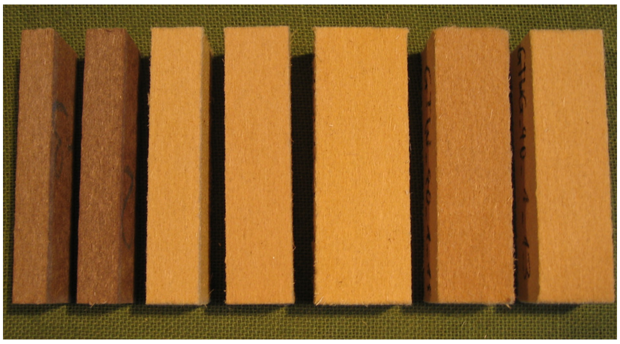

Figure 1: *WFIB – single-ply boards*

Figure 2: *WFIB – multilayer boards*

WFIB are used in different parts of buildings. In roofs, rain-tight sub plates (RTSP) are fixed as sub decking. A further insulation is possible as above-rafter or interim-rafter insulation with universal insulation boards (UIB). In walls, plaster baseboards (PB) may be used in composite thermal insulation systems. In figure 3 the different applications are shown.

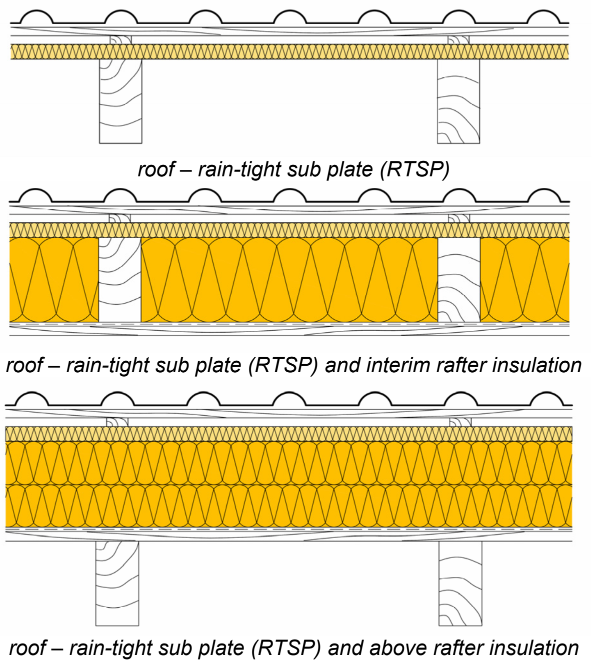

Figure 3: *Applications of WFIB*

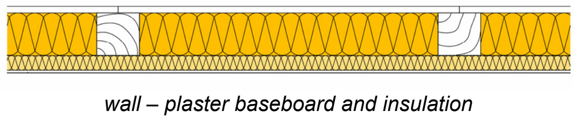

Figure 3 (cont.): *Applications of WFIB*

11 different WFIB of three different manufacturers were selected to analyse the characteristics needed for the use as sheathing in shear walls. The nominal density range was between 110 kg/m^3 and 270 kg/m^3. The densities and moisture contents of the tested boards were determined. The measured moisture content was 7.3% to 10.3%. Characteristic densities for the different types of WFIB are given in table 1.

Table 1: *Proposed characteristic density of WFIB*

WFIB type	Characteristic density in kg/m^3
Rain-tight sub plate (RTSB)	200
Plaster baseboard (PB)	150
Universal insulation board (UIB)	150
	100

3 ANALYSIS OF WALL PANELS

3.1 ANALYSIS ACCORDING TO GERMAN DESIGN CODE DIN 1052:2008-12

The analysis according to German design code DIN 1052 [1] is a simplified analysis for wall and roof panels. Three different failure modes are considered. Beside the failure of the connection between timber and sheathing material, shear failure and buckling failure of the sheathing panel are considered. The shear flow per wall panel length is obtained using Equation (1):

$$s_{v,0,d} = \frac{F_{v,d}}{\ell} \qquad (1)$$

where

$F_{v,d}$ = design value of horizontal load acting on wall panel and

ℓ = length of wall panel.

The shear strength per wall panel length is calculated according to Equation (2):

$$f_{v,0,d} = \min \left\{ \begin{array}{c} k_{v1} \cdot \dfrac{R_d}{a_v} \\ k_{v1} \cdot k_{v2} \cdot f_{v,d} \cdot t \\ k_{v1} \cdot k_{v2} \cdot f_{v,d} \cdot 35 \cdot \dfrac{t^2}{a_r} \end{array} \right\} \qquad (2)$$

where

k_{v1} = factor considering the joints at the panel boundaries (k_{v1} = 1, if panel boundaries fixed at all sides, else k_{v1} = 0.66),

k_{v2} = factor considering if the sheathing is one-sided (k_{v2} = 0.33) or both-sided (k_{v2} = 0.5),

R_d = design value of load-carrying capacity of the joint between sheathing and timber frame,
a_v = spacing of fasteners,
$f_{v,d}$ = design value of shear strength of sheathing panel,
t = thickness of sheathing panel and
a_r = spacing of vertical studs.

3.2 ANALYSIS ACCORDING TO EN 1995-1-1

The analysis according to EN 1995-1-1 [2] is a simplified analysis for wall and roof panels similar to the analysis in DIN 1052. However, the analysis only considers the failure of the connection between timber and sheathing material. The load-carrying capacity of a wall panel is obtained using Equation (3):

$$F_{i,v,Rd} = \frac{F_{f,Rd} \cdot b_i \cdot c_i}{s} \tag{3}$$

where
$F_{f,Rd}$ = design value of the load-carrying capacity of a single fastener,
b_i = length of wall panel,
s = spacing of fasteners.

Furthermore, the analysis considers the geometry of the wall panel by a factor c_i, see Equation (4):

$$c_i = \begin{cases} 1 & for \quad b_1 \geq b_0 \\ \dfrac{b_i}{b_0} & for \quad b_1 < b_0 \end{cases} \tag{4}$$

where
b_0 = $h/2$,
h = height of wall panel.

3.3 NECESSARY TESTS AND ANALYSIS

In both analysis methods the load-carrying capacity of the connection between timber member and sheathing panel is required. The analysis according to DIN 1052:2008-12 in addition requires the shear strength of the sheathing panel. The connection's load-carrying capacity is calculated according to Johansen's yield theory in both standards and depends on the geometry of the connection (thicknesses of the jointed members and diameter of the fastener), the yield moment of the fastener and the embedding strengths of the jointed members. The load-carrying capacity may be increased if the fastener can be loaded axially apart from loading laterally. If the fastener is driven in directly into the sheathing panel the axial load-carrying capacity depends on the withdrawal parameter of the fastener in the timber member and the head/crown pull-through resistance in the sheathing panel or a counter batten, if the fastener is driven in through a counter batten.
Johansen's theory considers six different failure mechanisms for single shear joints. In the first three failure mechanisms the embedding strength of one or both of the jointed members is reached. In failure modes four and five in addition one plastic hinge appears. In failure mode six two plastic hinges are formed. In joints with fasteners driven in through a counter batten the inclination of the fastener in failure modes 1a and 2b involves embedding resistances in the counter batten. Hence the related equations for these failure mechanisms are extended.

4 EMBEDDING STRENGTH OF WFIB

Tests with nails were performed according to EN 383 [3] to evaluate the embedding strength of mechanical fasteners in WFIB. The test set-up is shown in figure 4. In preliminary tests an influence of the angle between force and production direction could not be identified. About 600 embedment tests with five different diameters (d = 3.1/3.4/3.8/4.6/5.0 mm) were carried out. The test results for the embedding strength correlate with the measured densities of the test specimens. In figure 5 the embedding strength is plotted vs. the density. The correlation coefficient is r = 0.880.

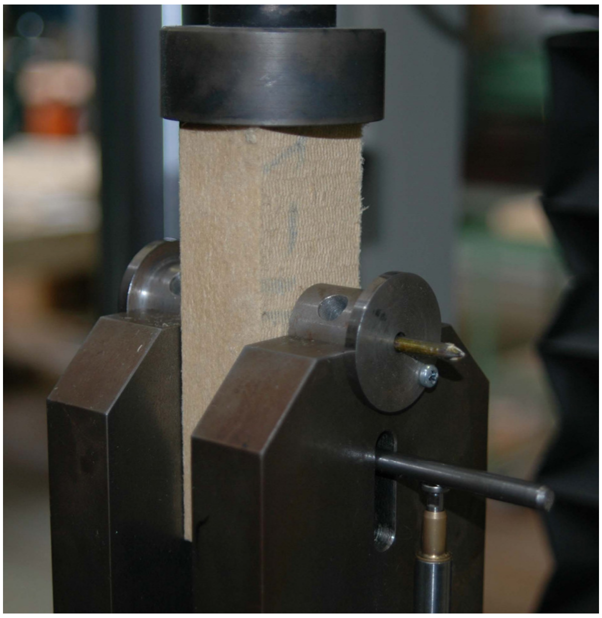

Figure 4: *Test - embedding strength of nails in WFIB*

There is a less pronounced correlation between the embedding strength and the thickness of the boards. A negative correlation exists between the embedding strength and the fastener diameter. Due to a correlation between the density and the thickness and the higher correlation between embedding strength and thickness, the parameters diameter and density are considered in a regression model for the embedding strength. By means of a multiple regression analysis, equation (5) was derived for the embedding strength f_h of WFIB.

$$f_\mathrm{h} = 18.5 \cdot 10^{-5} \cdot \rho^{2.04} \cdot d^{-0.74} \text{ in N/mm}^2 \tag{5}$$

where
ρ = density of the WFIB in kg/m^3 and
d = diameter of the fastener in mm.

In figure 6 the embedding strength values from the tests are plotted vs. the calculated embedding strength values. The correlation coefficient is r = 0.916. The slope of the regression straight is m = 1.02 and the y-intercept is b = -0.090.

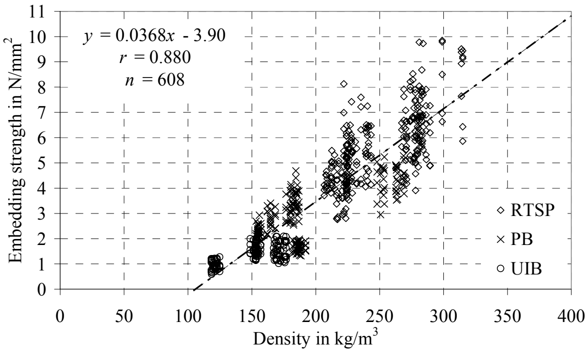

Figure 5: *Embedding strength vs. density*

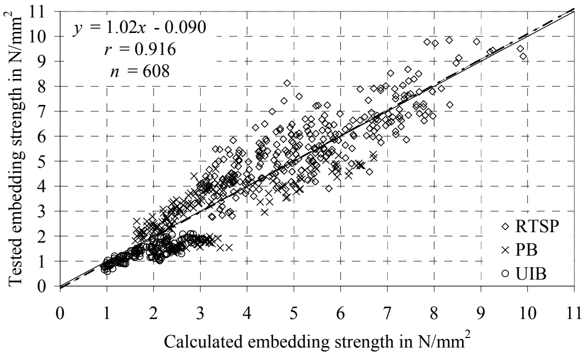

Figure 6: *Embedding strength from tests vs. calculated embedding strength*

Characteristic values of the embedding strength may be calculated considering the proposed characteristic densities for the different types of WFIB (table 2).

Table 2: *Characteristic embedding strength in N/mm²*

WFIB	Characteristic density in kg/m³	Characteristic embedding strength in N/mm²
RTSP	200	$f_{h,k} = 8.88 \cdot d^{-0.75}$
PB	150	$f_{h,k} = 4.25 \cdot d^{-0.75}$
UIB	150	$f_{h,k} = 3.53 \cdot d^{-0.75}$
UIB	100	$f_{h,k} = 1.57 \cdot d^{-0.75}$

5 CROWN PULL-THROUGH RESISTANCE OF WIDE-CROWN STAPLES IN WFIB

The load-carrying capacity according to Johansen's yield theory depends on the geometry of the connection (thicknesses of the connected members and diameter of the fastener), the embedding strengths of the members (for WFIB presented in chapter 4) and the yield moment of the fastener. The load-carrying capacity increases with increasing axial load-carrying capacity of the fastener. The rope effect depends on the withdrawal strength of the fastener in the first member and the head/crown pull-through resistance in the second member. Hence the crown pull-through resistance of wide-crown staples in WFIB was examined. The test set-up is shown in figure 7.

Figure 7: *Test – Crown pull-through resistance of wide-crown staples in WFIB*

According to EN 1383 [4] about 100 tests with RTSP and PB were carried out. For each of the 15 different WFIB at least four tests were performed. The displacement at maximum load correlates with the thickness of the WFIB. In figure 8 the displacement at maximum load is plotted vs. the thickness of the WFIB.

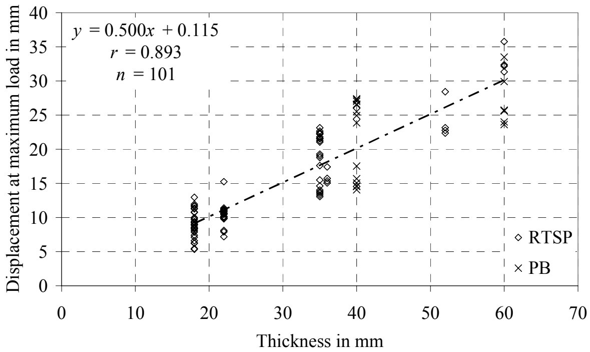

Figure 8: *Displacement at maximum load vs. thickness*

By means of a multiple regression analysis, equation (6) was derived to estimate the crown pull-through resistance $R_{ax,2}$ of staples in WFIB.

$$R_{ax,2} = 0.040 \cdot \rho^{1.17} \cdot t^{0.95} \text{ in N} \quad (6)$$

where

ρ = density of the WFIB in kg/m³ and
t = thickness of the WFIB in mm.

In figure 9 the crown pull-through resistance values from tests are plotted vs. the calculated values. The correlation coefficient is $r = 0.814$. The slope of the regression straight is $m = 1.01$ and the y-intercept is $b = -0.01$. The test results of a RTSP with relatively high thickness and density cannot be explained by the regression model, the test values are higher than the calculated values. Here, further tests are needed.

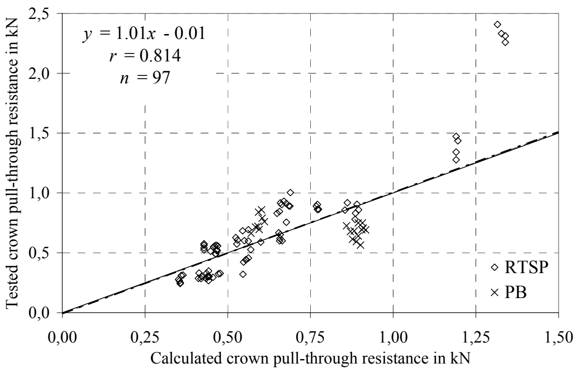

Figure 9: *Crown pull-through resistance from tests vs. calculated crown pull-through resistance*

Characteristic values of the crown pull-through resistance may be calculated considering the proposed characteristic densities for the different types of WFIB (equation (7)).

$$R_{\mathrm{ax,2,k}} = 0.032 \cdot \rho_{\mathrm{k}}^{1.17} \cdot t^{0.95} \text{ in N} \tag{7}$$

where

ρ_k = density of the WFIB in kg/m^3.

6 CALCULATION OF JOINTS BETWEEN TIMBER AND SHEATHING PANEL

The load-carrying capacity may be calculated according to Johansen's yield theory considering the different failure mechanisms. If the fastener is driven in through a counter batten, in failure modes 1a and 2b an extension of the existing equations is necessary. In failure modes 1a and 2b the embedding strength in the counter batten is reached and this effect increases the load-carrying capacity. The load path is from the stud into the sheathing board. There is no resulting load in the counter batten. Force and moment equilibrium, considering the existing embedding strength distribution and the yield moment, result in equation (8) for the extended failure mode 1a and equation (9) for the extended failure mode 2b. The failure modes with the influence of the counter batten are shown in figure 10 and figure 11.

$$R = \frac{f_{\mathrm{h},1} \cdot t_1 \cdot d}{1+\beta_2} \left[\sqrt{\beta_2 + 2\beta_2^2 \left[1 + \left(\frac{t_2}{t_1} \right) + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta_2^3 \left(\frac{t_2}{t_1} \right)^2 + \beta_2 \cdot \beta_3 \left(1+\beta_2 \right) \left(\frac{t_3}{t_1} \right)^2} - \beta_2 \left(1 + \frac{t_2}{t_1} \right) \right] \tag{8}$$

$$R = \frac{f_{\mathrm{h},1} \cdot t_2 \cdot d}{1+2\beta_2} \left[\sqrt{2\beta_2^2 \left(1+\beta_2 \right) + \frac{4\beta_2 \left(1+2\beta_2 \right) M_y}{f_{h1} \cdot d \cdot t_2^2} + \beta_2 \cdot \beta_3 \left(1+2\beta_2 \right) \left(\frac{t_3}{t_2} \right)^2} - \beta_2 \right] \tag{9}$$

where

t_3 = thickness of the counter batten,

$f_{h,3}$ = embedding strength of the counter batten and

$$\beta_2 = \frac{f_{\mathrm{h},2}}{f_{\mathrm{h},1}}$$

$$\beta_3 = \frac{f_{\mathrm{h},3}}{f_{\mathrm{h},1}}$$

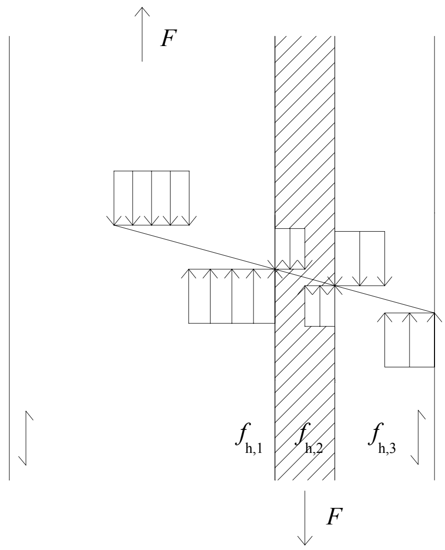

Figure 10: *Consideration of the counter batten in failure mode 1a*

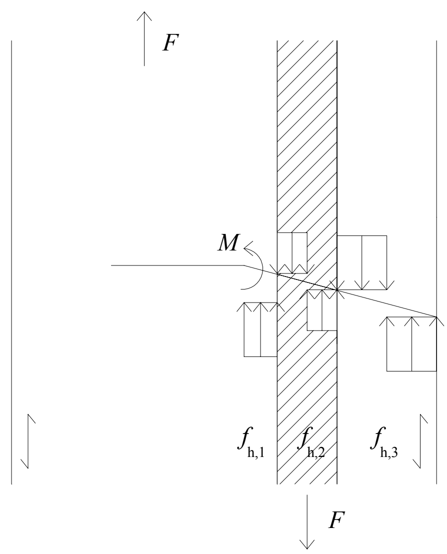

Figure 11: *Consideration of the counter batten in failure mode 2b*

7 LOAD-CARRYING CAPACITY AND STIFFNESS OF TIMBER-WFIB-JOINTS WITH NAILS AND STAPLES

In order to verify the results obtained in the tests presented in chapter 4 and 5 and to examine the stiffness of joints, further tests were performed.
In the previous paragraphs the basic parameters (embedding strength and crown pull-through resistance) for the calculation of the load-carrying capacity of timber-WFIB-joints were determined. The calculation method according to Johansen's yield theory was extended for fasteners driven in through a counter batten. In tests with joints the calculated values considering the determined parameters are checked. Furthermore the stiffness of timber-WFIB-joints was evaluated. RTSP of three manufacturers in three thicknesses, respectively, and PB were used as sheathing panel. Nails and staples were driven in through a counter batten. Wide-crown staples were driven in directly. In figure 12 and figure 13 the test specimens for the tests with nails and staples are shown. In figure 14 the test set-up is shown.

The load-carrying capacity may be obtained according to Johansen's yield theory considering the test results and the extended calculation model. The yield moments of the fasteners were evaluated according to EN 409 [5]. The embedding strength of staples in WFIB was calculated according to equation (1) assuming the validity for diameters smaller than the tested ones. The embedding strength of nails in WFIB was determined in tests and used for the calculation. The embedding strength of the fastener in the timber member was calculated according to DIN 1052 [1] considering the specimen densities. The withdrawal resistance and the pull-through resistance were calculated according to DIN 1052 [1] for nails and staples. The crown pull-through resistance for wide-crown staples was determined in tests.

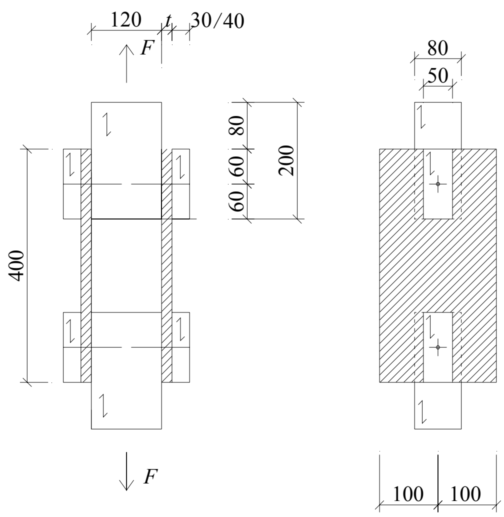

Figure 12: *Test specimen for test of timber-WFIB-joints with nails and staples driven in through a counter batten*

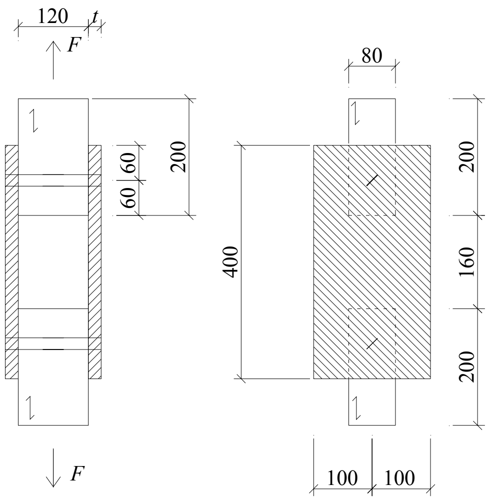

Figure 13: *Test specimen for test of timber-WFIB-joints with wide-crown staples driven in directly*

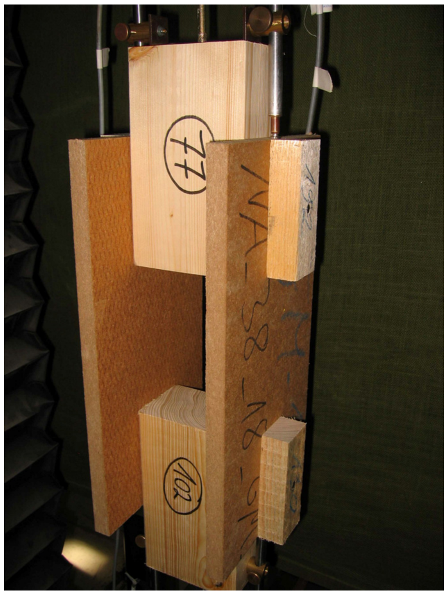

Figure 14: *Test specimen for test of timber-WFIB-joints*

The tests were carried out according to EN 26891 [6]. The maximum load was reached at a displacement of 15 mm. Although failure mode 1b was governing in the calculation for nails, failure mode 3 was observed in the tests. This may be explained by friction between the joint members. The relative deformations between WFIB and stud were measured at each of the four fasteners. The analysis of the joint stiffness considers a linear load-displacement behaviour up to 40% of the maximum load. In the tests non-linear load-displacement behaviour was observed. Due to this the analysis of the stiffness was calculated for a constant displacement of 0.3 mm. The load-carrying capacity from tests is plotted vs. the calculated load-carrying capacity in figure 15 for nails, in figure 16 for staples and in figure 17 for wide-crown staples.

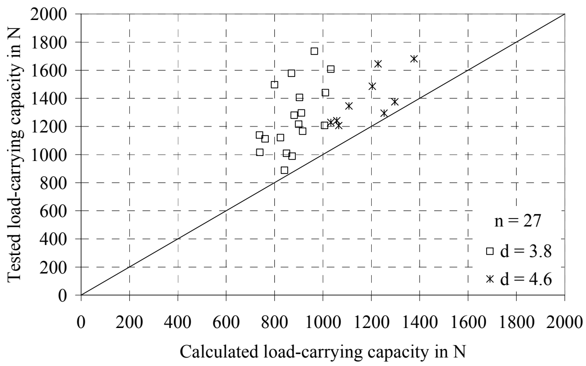

Figure 15: *Load-carrying capacity from tests vs. calculated load-carrying capacity for nails driven in through a counter batten*

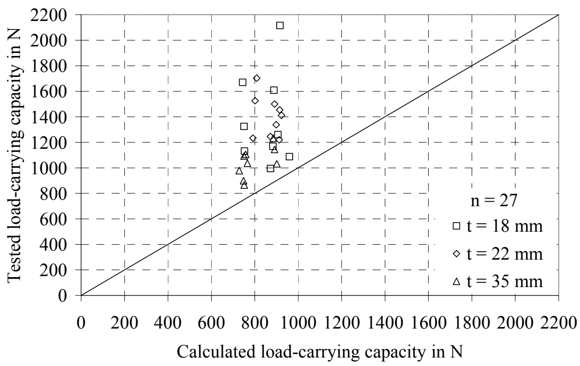

Figure 16: *Load-carrying capacity from tests vs. calculated load-carrying capacity for staples driven in through a counter batten*

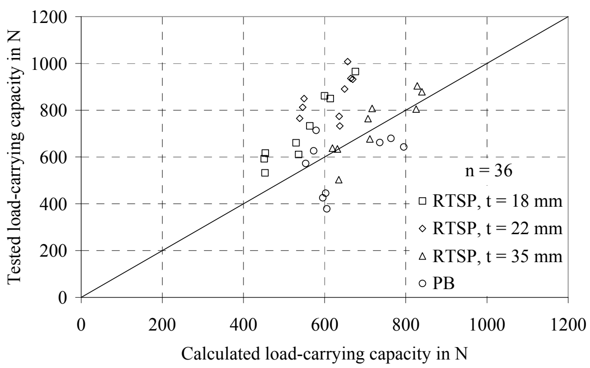

Figure 17: *Load-carrying capacity from tests vs. calculated load-carrying capacity for wide-crown staples*

By means of a multiple regression analysis, equation (10) was derived to calculate the stiffness of a timber-WFIB-joint. In figure 18 the stiffness from tests is plotted vs. the calculated stiffness. The correlation coefficient is $r = 0.898$.

$$K_{ser} = 1.25 \cdot \rho_{WFIB}^{0.80} \cdot \rho^{0.30} \cdot t^{-0.32} \cdot d^{1.29} \text{ in N/mm} \qquad (10)$$

where

ρ_{WFIB}	=	density of the WFIB in kg/m^3,
ρ	=	density of timber in kg/m^3,
t	=	thickness of WFIB in mm and
d	=	diameter of fastener in mm.

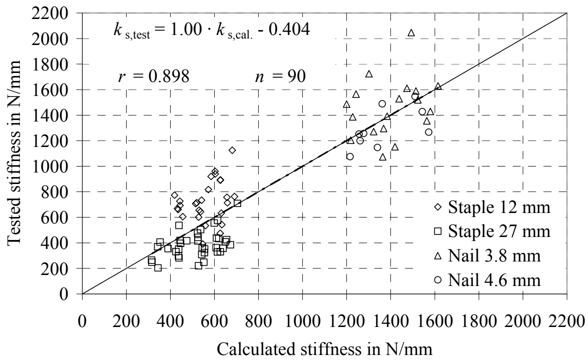

Figure 18: *Stiffness from tests vs. calculated stiffness*

8 SHEAR STRENGTH AND SHEAR MODULUS OF WFIB

The shear strength and the shear modulus of WFIB were determined according to EN 789 [7]. The geometry of the test specimens and the test set-up are shown in figure 19 and figure 20. The WFIB specimens were reinforced by four lateral timber boards connected with the WFIB test specimen by five pre-stressed bolts.

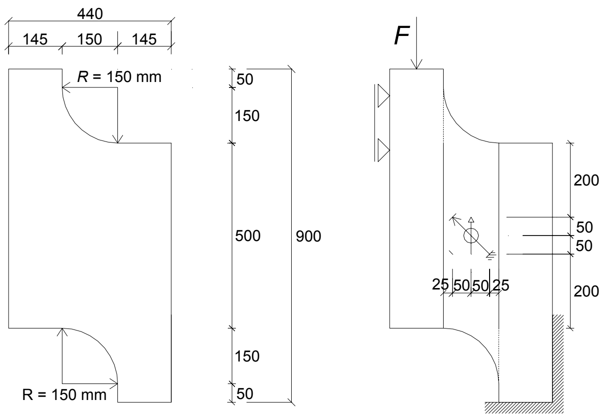

Figure 19: *Geometry of test specimen and test set-up*

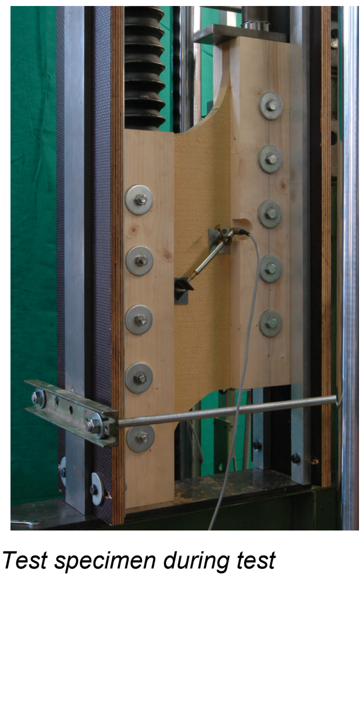

Figure 20: *Test specimen during test*

The correlation between shear strength, density and panel thickness was analysed. The correlation coefficient between shear strength and board thickness is $r = -0.544$, while the correlation coefficient between shear strength and density is $r = 0.847$ and between density and board thickness is $r = -0.429$. The shear strength may be assessed by Equation (11). Figure 21 shows the shear strength vs. the density.

$$f_v = 1.30 \cdot 10^{-6} \cdot \rho^{2.39} \text{ in N/mm}^2 \quad (11)$$

where
ρ = density of the WFIB in kg/m³.

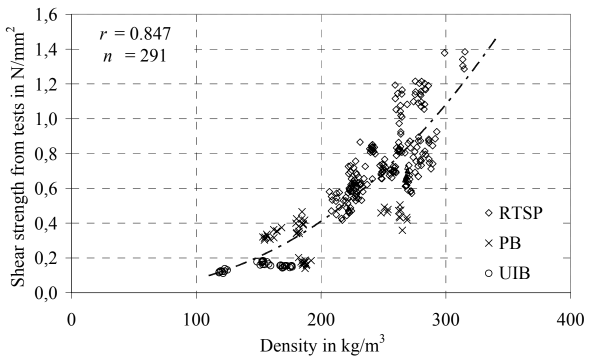

***Figure 21:** Shear strength from tests vs. density*

The shear modulus is plotted vs. the density in Figure 22. The correlation coefficient between shear modulus and density is $r = 0.894$. The shear strength may be assessed by Equation (12).

$$G = 9.03 \cdot 10^{-4} \cdot \rho^{2.13} \text{ in N/mm}^2 \quad (12)$$

where
ρ = density of the WFIB in kg/m³.

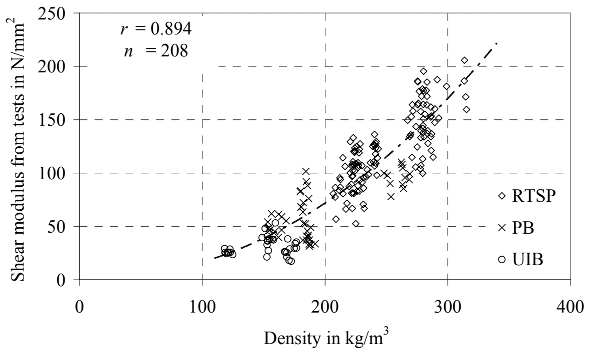

Figure 22: Shear modulus from tests vs. density

9 CONCLUSIONS

To date wood fibre insulation boards are used as acoustic and thermal insulation. As wood-based panels they can also be used for the load transfer in wall panels. The load transfer requires a sufficient load-carrying capacity of the joint between studs and sheathing and sufficient shear strength of the WFIB. In order to calculate the load carrying capacity of joints between timber and WFIB the embedding strength of nails in WFIB and the crown pull-through resistance of wide-crown staples in WFIB were determined. Johansen's theory was extended to consider the influence of a counter batten on the load carrying capacity. The stiffness of joints between timber and WFIB was evaluated in further tests. The shear strength and shear modulus of WFIB were also determined in tests. The results serve as a basis for the analysis of wood fibre insulation boards as sheathing panel in timber frame construction.

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[3] EN 383:1993-10 Timber structures; Test methods; Determination of embedding strength and foundation values for dowel type fasteners
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[5] EN 409:1993-10 Timber structures; Test methods; Determination of the yield moment of dowel type fasteners; Nails
[6] EN 26891:1991-07 Timber structures; Joints made with mechanical fasteners; General principles for the determination of strength and deformation characteristics (ISO 6891:1983)
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