Technical Assessment of the KG 700 & KL 500 Haubold Staples Used in Timber Frame Wall Construction

Commercial in Confidence

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1. Brief

In accordance with the agreement TRADA Technology (TRADA) has entered with Josef Kihlberg Ltd (client), dated 12 July 2000, TRADA has carried out the technical assessment of selected 'Haubold' staples, which covers the derivation of the capacity of selected staples when fixing certain sheathing panels to timber members in accordance with British Standards and a specification to enable the use of staples in the construction of timber frame walls in the UK.

The findings of the technical assessment of selected 'Haubold' staples in their intended use (timber frame wall applications) are presented in this report, which is part of the process of enabling the client to seek certification for use of these products in the UK from a certification body.

This report is the second one prepared for the client.

2. Product description

The staples assessed are manufactured by Haubold-Kihlberg GmbH in Germany.

2 types of staples were assessed, KG 700 and KL 500, which are available in a range of lengths. Due to the staples' use (fixing sheathing to the timber sub-frame) and the length of nails specified in BS 5268, Part6 (1996) for that purpose, 2 sizes of 'Haubold' staples were assessed in consultation with the client, which are as follows:

	Wire diameter (mm)	Length (mm)	Crown width (mm)
KG 700	1.53	50	11.20
KL 500	1.15	40	11.00

Although the 2 staples have a slightly barrel shape wire cross-section, a wire diameter is used. Both staples have a sufficient length when related to the sheathing board's thickness (both staples' length is greater than 2.5 times the board's thickness).

The tolerances are ±0.04 mm in wire diameter and ±0.03 mm in crown width.

Both staples have a zinc coating minimum 7µm thick all around the staple. In addition, the KG 700 and KL 500 staples, 50mm and 40mm long respectively have a resin coating in the legs over a 28mm length and 23mm respectively.

3. Scope of use

The selected 'Haubold' staples have been assessed for the sole use of fixing sheathing panels to a timber sub-frame (studs, top and bottom plate) in timber frame wall construction, ensuring that the wall provides adequate racking resistance as calculated by the designer in accordance with BS 5268-6.1. The range of sheathing materials is covered in section 4.1.

Hence, it is noted that the use of these staples for other purposes is not covered by this assessment.

4. Technical Assessment

4.1 Timber frame wall specifications

The sheathing panels used to assess the KG 700 & KL 500 staples included the ones complying with BS 5268: Section 6.1: 1996 and classified as category 1, 2 or 3 in terms of the racking resistance they provide and their nailing requirement. Modern sheathing materials, usually proprietary, that at the same time provide thermal insulation and/or fire resistance, e.g. 'Fermacell', 'Panel Vent', were also used in the assessment of the selected 'Haubold' staples. The sheathing materials used are shown in Table 1:

Category (BS 5268-6.1)	Sheathing Material	Thickness (mm)
1	OSB	9
1	Plywood Type I	9.5
1	Cement Bonded Particleboard	12
1	'Panel Vent' Mediumboard	9
1	'Fermacell' Gypsum Fibreboard	12.5
1	Chipboard	12
2	Bitumen Impregnated Insulation Board	12.5

Table 1: Sheathing materials used in the assessment of staples

Plasterboard used as category 2 sheathing panel, when in 2 layers in a separating wall, or category 3 when used as lining was not considered in the assessment of staples, since staples are not considered acceptable in fire, until proven otherwise with the means of fire tests. In addition, the latest standard practice in fixing plasterboard in timber frame walls is to use 3.5mm diameter, 38mm long dry wall screws instead of nails or staples to prevent the fixings from pulling through the plasterboard.

Although the studs and plates typically used in timber frame wall construction in the UK are 38x89 C16, four grades of timber (forming the sub-frame in a timber-frame wall) were used in the assessment of KG 700 & KL 500 staples, i.e. C16, C18, C22 and C24, with timber members being C18 and C22 considered as C16 in terms of the capacity achieved by the staples. Likewise, timber members of a grade better than C24 should be assumed to be C24 in terms of the capacity of staples.

4.2 Expressions to obtain basic shear lateral load of staples fixing a sheathing panel to timber members in a timber frame wall in the UK

The basic shear lateral load capacity of the KG 700 and KL 500 'Haubold' staples when fixing a sheathing panel (from Table 1 in section 4.1) to a timber member was derived in accordance with BS 5268: Part 2: 1996. Although this Standard does not address the design of staples specifically, it provides guidance for the assessment of nailed joints and it contains a series of expressions for obtaining the capacity of nails. DD ENV 1995-1-1: 1994 (Eurocode 5), section 6.4 was used to model a staple as being the equivalent of 2 nails, each leg being one nail with a diameter equal to the wire diameter of the staple.

BS 5268-2 and EC5 share the same philosophy of design (Johanson's theory) for the design of nailed joints, even though BS 5268-2 provides permissible values for ease of design, and as such they share the same expressions to obtain shear capacities, with the only difference being the safety factors included in the design. BS 5268-2 makes use of F_d and K_d, whereas EC5 uses γ_m (a fastener material safety factor) and k_{mod} (a factor that accounts for duration of load and moisture content of timber). Hence, the shear capacity of the KG 700 and KL 500 staples was derived in accordance with BS 5268, producing permissible values.

The basic shear lateral load of a KG 700 and KL 500 'Haubold' staple is:

$$F = 2 * \frac{1}{F_d} \frac{1}{K_d} * \min\{F_1, F_2, F_3, F_4, F_5, F_6\}$$

provided that the staple is driven through the sheathing at almost right angles into the grain of the timber and are fully embedded in the timber, where equations (1) through (6) represent the potential failure modes which are as follows:

(1) Sheathing panel failure

$$F_1 = f_{h,1,d} * t_1 * d$$

(2) Timber member failure

$$F_2 = f_{h,1,d} * t_2 * d * b$$

(3) Failure of both the sheathing panel and timber member

$$F_3 = \frac{f_{h,1,d} * t_1 * d}{1 + b} * \left[\sqrt{b + 2b^2 \left(1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1}\right)^2\right) + b^3 \left(\frac{t_2}{t_1}\right)^2} - b\left(1 + \frac{t_2}{t_1}\right) \right]$$

(4) Staple failure in timber

$$F_4 = 1.1 \frac{f_{h,1,d} * t_1 * d}{2 + b} * \left[\sqrt{2b + (1 + b) + \frac{4b(2 + b)M_{y,d}}{f_{h,1,d} d t_1^2}} - b \right]$$

(5) Staple failure in sheathing

$$F_5 = 1.1 \frac{f_{h,1,d} * t_2 * d}{1 + 2b} * \left[\sqrt{2b^2 + (1 + b) + \frac{4b(1 + 2b)M_{y,d}}{f_{h,1,d} d t_2^2}} - b \right]$$

(6) Staple failure in both the sheathing panel and timber member

$$F_6 = 1.1 * \sqrt{\frac{2b}{1 + b}} * \sqrt{2M_{y,d} f_{h,1,d} d}$$

where:

F_d = 1.4
K_d = 1.12
t_1 = the thickness of the sheathing panel [mm]
t_2 = the pointside penetration of the staple in the timber [mm]
d = the wire diameter of the staple [mm]

$M_{y,d}$ = the staple yield moment = $164*d^{2.6}$ [Nmm]
$f_{h,1,d}$ = the embedding strength of the staple in sheathing
= $0.068*(1/\rho_k*d^{0.3})$ [N/mm²]
$f_{h,2,d}$ = the embedding strength of the staple in timber
= $0.05*(1/\rho_k*d^{0.3})$ [N/mm²]
β = $f_{h,2,d}/f_{h,1,d}$
ρ_k = the 5th percentile characteristic density at 15% moisture content (for both the sheathing material and the timber)

In regard to the moisture content at which the sheathing and timber should be considered, although Annex G of BS 5268-2 recommends a MC of 12%, a MC of 15% is closer to the moisture content expected in service. Furthermore, a 12% MC would force the mode failure to occur in the connecting members. The 5th percentile characteristic density of the sheathing materials should be obtained from prEN 12369-1 for standard materials (at 20% MC) or from manufacturers (at 20% MC) and for timber from Table 7, BS 5268-2 (1996) which is given at 18% MC (since the 1991 version contains the same values at 18% MC). The characteristic density at a higher MC should be converted to 15%MC using the following formulas:
$(\rho_k)_{15\%MC} = (1.15/1.20)*(\rho_k)_{20\%MC}$ and $(\rho_k)_{15\%MC} = (1.15/1.18)*(\rho_k)_{18\%MC}$

4.3 Basic shear lateral load (BS 5268-2 compatible) for KG 700 & KL 500 'Haubold' staples when fixing sheathing panels to timber sub-frame

The basic shear lateral load, compatible with BS 5268-2 (1996) of KG 700 and KL 500 'Haubold' staples when fixing certain sheathing materials to timber was found to be as follows:

- **KG 700 Haubold staple - 1.53mm diameter - 50mm long (basic shear load - BS 5268-2 compatible)**

Sheathing (mm)	Timber	Mode of Failure	Capacity(N)
OSB (9)	C16/18/22	Staple failure in timber	**223.6**
Plywood (9.5)	C16/18/22	Staple failure in timber	**228.7**
Cement bonded particleboard (12)	C16/18/22	Staple failure in both members	**241.9**
Panel Vent (9)	C16/18/22	Staple failure in both members	**241.9**
Fermacell (12.5)	C16/18/22	Staple failure in both members	**256.0**
Chipboard (12)	C16/18/22	Staple failure in both members	**241.9**
Bitumen impregnated insulation board (12.5)	C16/18/22	Staple failure in timber	**194.7**

Sheathing (mm)	Timber	Mode of Failure	Capacity(N)
OSB (9)	C24 or better	Staple failure in timber	**231.2**
Plywood (9.5)	C24 or better	Staple failure in timber	**236.3**
Cement bonded particleboard (12)	C24 or better	Staple failure in both members	**252.8**
Panel Vent (9)	C24 or better	Staple failure in timber	**251.9**
Fermacell (12.5)	C24 or better	Staple failure in both members	**269.1**
Chipboard (12)	C24 or better	Staple failure in both members	**252.8**
Bitumen impregnated insulation board (12.5)	C24 or better	Staple failure in timber	**199.8**

Table 2: Basic shear load of a KG 700 staple fixing sheathing to timber

- **KL 500 Haubold staple - 1.15mm diameter - 40mm long (basic shear load - BS 5268-2 compatible)**

Sheathing (mm)	Timber	Mode of Failure	Capacity(N)
OSB (9)	C16/18/22	Staple failure in both members	**147.5**
Plywood (9.5)	C16/18/22	Staple failure in both members	**147.2**
Cement bonded particleboard (12)	C16/18/22	Staple failure in both members	**151.0**
Panel Vent (9)	C16/18/22	Staple failure in both members	**151.0**
Fermacell (12.5)	C16/18/22	Staple failure in both members	**159.9**
Chipboard (12)	C16/18/22	Staple failure in both members	**151.0**
Bitumen impregnated insulation board (12.5)	C16/18/22	Staple failure in both members	**132.1**

Sheathing (mm)	Timber	Mode of Failure	Capacity(N)
OSB (9)	C24 or better	Staple failure in both members	**153.8**
Plywood (9.5)	C24 or better	Staple failure in both members	**153.4**
Cement bonded particleboard (12)	C24 or better	Staple failure in both members	**157.8**
Panel Vent (9)	C24 or better	Staple failure in both members	**157.8**
Fermacell (12.5)	C24 or better	Staple failure in both members	**168.0**
Chipboard (12)	C24 or better	Staple failure in both members	**157.8**
Bitumen impregnated insulation board (12.5)	C24 or better	Staple failure in both members	**136.6**

Table 3: Basic shear load of a KL 500 staple fixing sheathing to timber

4.4 Permissible shear lateral load of staples - BS 5268-2 compatible

The basic loads given in Tables 2 and 3 for each staple are also the permissible loads for long-term (permanent) loads and service classes 1 and 2. However, for loads of different duration and also different service classes, the permissible shear lateral load for the KG 700 and KL 500 staples should be modified to account for duration of load and moisture content, using the K_{DOL} and K_{MC} factors, as given below:

Duration of load	Long-term	Medium-term	Short-term & very short-term
K_{DOL}	1.00	1.12	1.25

Moisture content	Service classes 1 & 2	Service class 3
K_{MC}	1.00	0.70

The permissible shear lateral load for a staple is as follows:

$F_{adm} = F * K_{DOL} * K_{MC}$ [in Newtons]

4.5 Lateral load capacity obtained with alternative ways

The basic shear load was also obtained using the German Standard DIN 1052, Part 2 (1988), which is as follows:

Haubold staple	DIN 1052-2 Basic Shear Load
KG 700	203.0 N
KL 500	118.6 N

Although the approach followed by DIN 1052-2 is conservative (the basic shear load obtained in accordance with DIN 1052-2 is lower than the one obtained in accordance with BS 5268-2), the German Standard fails to account for the strength of the connecting members (sheathing panel and timber stud or plate) and differentiate accordingly.

An alternative approach applied to obtain the capacity of a staple was to consider a staple as one nail with a diameter 1.5 times the diameter of the staple (Timber Frame Housing - Structural Recommendations, TRADA, 1989). That approach gave on average approximately the same capacity as the EC5 approach (treat each staple leg as one nail) but a considerably higher variability depending on the sheathing and timber. The capacities obtained for staples KG 700 & KL 500 following this approach are shown in Appendix A (Tables 2 and 3).

4.6 Fixing requirements in timber frame walls (BS 5268-6.1: 1996)

The fixing requirements that BS 5268: Section 6.1: 1996 provides for nails is:

Racking	Nails	Spacing
Category 1	3.00mm diameter, 50mm long	150mm on perimeter, 300mm internal
Category 2 except plasterboard	3.00mm diameter, 50mm long	75mm on perimeter, 150mm internal

Having assessed in terms of shear capacity the required by BS 5258-6.1 nails and the KG 700 and KL 500 staples, their ratio in terms of shear capacity was found, as shown in Table 4.

Sheathing (mm)	Timber	Required Nail (N)	KG 700 (N)	KG 700-Nail Ratio	KL 500 (N)	KL 500-Nail Ratio
OSB (9)	C16	261.7	223.6	**0.85**	147.5	**0.56**
	C24	277.8	231.2	**0.83**	153.8	**0.55**
Plywood (9.5)	C16	260.0	228.7	**0.88**	147.2	**0.57**
	C24	279.5	236.3	**0.85**	153.4	**0.55**
Cement bonded particleboard (12)	C16	279.2	241.9	**0.87**	151.0	**0.54**
	C24	301.8	252.8	**0.84**	157.8	**0.52**
Panel Vent (9)	C16	275.4	241.9	**0.88**	151.0	**0.55**
	C24	292.1	251.9	**0.86**	157.8	**0.54**
Fermacell (12.5)	C16	343.7	256.0	**0.74**	159.9	**0.47**
	C24	369.8	269.1	**0.73**	168.0	**0.45**
Chipboard (12)	C16	279.2	241.9	**0.87**	151.0	**0.54**
	C24	301.8	252.8	**0.84**	157.8	**0.52**
Bitumen impregnated insulation board (12.5)	C16	211.3	194.7	**0.92**	132.1	**0.63**
	C24	228.1	199.8	**0.88**	136.6	**0.60**

Table 4: Comparison in terms of shear capacity of KG 700 & KL 500 staples with the nails required by BS 5268-6.1 (1996)

Based on the shear capacity ratio of the 2 staples compared to the required by BS 5268-6.1 nail, KG 700 achieving 80% and KL 500 50% the capacity of the required nail, a spacing specification was produced for KG 700 and KL 500 'Haubold' staples in the construction of racking walls in accordance with BS 5268-6.1 (1996). In the case of a very dense material, such as 'Fermacell' having a density of 1100 kg/m^3, the comparative ratio of the 2 staples drop below 80% and 50% respectively. However, although the ratio drops, the actual capacity of the 2 staples when fixing very dense sheathing panels increases. This is because the capacity of the nails increases more than the staples' capacity when fixing very dense sheathing. It is understood however, that the intention of BS 5268-6.1 was not to require a much higher fixing capacity for a denser sheathing. Hence, the same spacing specification is kept for all sheathing materials because, as stated above, the 2 staples provide adequate shear capacity.

Consequently, the following spacing specification is produced for KG 700 and KL 500 'Haubold' staples in timber frame wall construction in accordance with BS 5268-6.1 (1996):

Racking	Staples	Spacing
Category 1 (OSB, Plywood, Cement particle-board, Panel Vent, Fermacell, Chipboard)	KG 700 - 50mm long	120mm on perimeter, 240mm internal
	KL 500 - 40mm long	75mm on perimeter, 150mm internal
Category 2 except plasterboard (Bitumen insulation board)	KG 700 - 50mm long	60mm on perimeter, 120mm internal
	KL 500 - 40mm long	35mm on perimeter, 75mm internal

Table 5: Fixing specification of racking walls in accordance with BS 5268-6.1 (1996) using KG 700 and KL 500 'Haubold' staples

In regard to the spacing of the staples around the edge of the sheathing panel, staples should be positioned so that the edge of the sheathing panel, or the face of the stud/plate, is not less than 7mm. Spacing less than 35mm on centres, should be avoided, particularly parallel to the grain of the timber stud or plate, to prevent splitting in the timber.

4.7 History of use - Practicability

Staples are used extensively in some European countries and North America for fixing wall panels to the timber sub-frame. 'Haubold' staples have been used in Germany for several years.

The use of staples, when fixing sheathing panels to the timber sub-frame in a timber frame wall, offers advantages in terms of cost and speed. 'Haubold' staples KG 700 and KL 500 are fixed to the connecting members with the use of an automatic gun.

Because staples are driven into the connecting surfaces with an automatic gun, care must be exercised not to under-drive the staple (so that sufficient penetration depth is achieved) and not to overdrive the staple in order to prevent the staple from pulling through the sheathing panel.

End and edge distances in accordance with BS 5268, as well as the specified spacings in this report, should be followed to avoid failure of the sheathing panel around its edges.

TRADA is not aware of any problems or failures of the 'Haubold' staples KG 700 and KL 500 when fixing sheathing panels to a timber sub-frame.

4.8 Durability

KG 700 and KL 500 staples are manufactured in accordance with DIN 1052-2 and as such they comply with the corrosion protection requirements of the German Standard. KG 700 and KL 500 are required, by DIN 1052-2, to have a galvanising coating of 7μm minimum thickness, equivalent to 50g/m² minimum zinc mass, which should provide adequate resistance against corrosion in internal and covered environments. Verification of the adequacy of the galvanising coating in providing corrosion resistance is carried out in Germany in accordance with DIN 50988-1.

In addition, both staples have a resin coating around the staple's legs, over at least half the legs' length, which provides additional corrosion protection as well as better bonding to the connecting members.

BS 5268 (Part 2 and Section 6.1) provides only a generic requirement in regard to corrosion protection by specifying that all nailed joints should be anti-corrosion treated.

As already stated, no technical data in the form of fire test results have been submitted to TRADA in order to assess the behaviour of the Haubold staples in a fire in uses where specific fire resistance is required.

'Haubold' staples KG 700 and KL 500 are subject to an ongoing manufacturing quality control in accordance with DIN 50049-2.

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Issued under the authority of:

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Date: 17 August 2000

APPENDIX A

Table 1: **Derivation of basic shear lateral load of 3.00mm diameter, 50mm long nail**

Table 2: **Derivation of basic shear lateral load of KG 700 'Haubold' staple**

Table 3: **Derivation of basic shear lateral load of KL 500 'Haubold' staple**

Table 1 Derivation of basic shear lateral load - NAIL 3.00mm diam, 50mm long

Fd	Kd
1.4	1.12

Category 1 & 2 Materials (excl. plasterboard)

	Sheathing Panel		Timber (C16/18/22)															
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**F(N)**
OSB(9mm)	550	527.1	310	302.1	3	9	41	2853.4	25.8	10.9	0.42	696.0	1336.3	410.3	419.6	635.2	562.7	261.7
Ply(9.5mm)	-	518.5	310	302.1	3	9.5	40.5	2853.4	25.4	10.9	0.43	722.7	1320.0	407.7	422.4	628.5	561.4	260.0
Cement(12)	650	622.9	310	302.1	3	12	38	2853.4	30.5	10.9	0.36	1096.7	1238.6	437.8	484.2	611.4	576.0	279.2
PanelVent(9)	650	622.9	310	302.1	3	9	41	2853.4	30.5	10.9	0.36	822.6	1336.3	431.9	440.7	645.4	576.0	275.4
Fermacell(12.5)	1100	1054.2	310	302.1	3	12.5	37.5	2853.4	51.6	10.9	0.21	1933.4	1222.3	538.9	619.4	629.9	609.7	343.7
Chipboard(12)	650	622.9	310	302.1	3	12	38	2853.4	30.5	10.9	0.36	1096.7	1238.6	437.8	484.2	611.4	576.0	279.2
Bitumen(12.5)	300	287.5	310	302.1	3	12.5	37.5	2853.4	14.1	10.9	0.77	527.3	1222.3	331.4	369.6	551.6	503.9	211.3

	Sheathing Panel		Timber (C24)															
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**F(N)**
OSB(9mm)	550	527.1	350	341.1	3	9	41	2853.4	25.8	12.3	0.48	696.0	1508.8	445.8	435.6	697.2	586.8	277.8
Ply(9.5mm)	-	518.5	350	341.1	3	9.5	40.5	2853.4	25.4	12.3	0.48	722.7	1490.4	442.6	438.2	689.5	585.3	279.5
Cement(12)	650	622.9	350	341.1	3	12	38	2853.4	30.5	12.3	0.40	1096.7	1398.4	473.3	502.3	670.5	601.9	301.8
PanelVent(9)	650	622.9	350	341.1	3	9	41	2853.4	30.5	12.3	0.40	822.6	1508.8	469.9	458.1	709.3	601.9	292.1
Fermacell(12.5)	1100	1054.2	350	341.1	3	12.5	37.5	2853.4	51.6	12.3	0.24	1933.4	1380.0	579.8	645.1	693.0	640.7	369.8
Chipboard(12)	650	622.9	350	341.1	3	12	38	2853.4	30.5	12.3	0.40	1096.7	1398.4	473.3	502.3	670.5	601.9	301.8
Bitumen(12.5)	300	287.5	350	341.1	3	12.5	37.5	2853.4	14.1	12.3	0.87	527.3	1380.0	357.6	380.7	600.4	521.0	228.1

Table 2 Derivation of basic shear lateral load - KG 700 STAPLE 1.53mm wire diam, 50mm long

Fd	Kd
1.4	1.12

Category 1 & 2 Materials (excl. plasterboard)

	Sheathing Panel		Timber (C16/18/22)																		Staple/Nail		
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**1/2 F(N)**	**F(N)**		**Ratio**	**DIN 1052-2**	**TRADA**
OSB(9mm)	550	527.1	310	302.1	1.53	9	41	495.5	31.5	13.3	0.42	434.4	834.1	256.1	175.3	357.2	185.3	111.8	223.6		0.85	203.0	183.9
Ply(9.5mm)	-	518.5	310	302.1	1.53	9.5	40.5	495.5	31.0	13.3	0.43	451.1	823.9	254.5	179.3	352.7	184.8	114.3	228.7		0.88	203.0	186.3
Cement(12)	650	622.9	310	302.1	1.53	12	38	495.5	37.3	13.3	0.36	684.5	773.1	273.3	231.7	338.5	189.6	120.9	241.9		0.87	203.0	224.4
PanelVent(9)	650	622.9	310	302.1	1.53	9	41	495.5	37.3	13.3	0.36	513.4	834.1	269.6	190.7	362.6	189.6	120.9	241.9		0.88	203.0	195.9
Fermacell(12.5)	1100	1054.2	310	302.1	1.53	12.5	37.5	495.5	63.1	13.3	0.21	1206.7	762.9	336.4	327.4	346.8	200.7	128.0	256.0		0.74	203.0	249.9
Chipboard(12)	650	622.9	310	302.1	1.53	12	38	495.5	37.3	13.3	0.36	684.5	773.1	273.3	231.7	338.5	189.6	120.9	241.9		0.87	203.0	224.4
Bitumen(12.5)	300	287.5	310	302.1	1.53	12.5	37.5	495.5	17.2	13.3	0.77	329.1	762.9	206.8	152.7	306.3	165.9	97.4	194.7		0.92	203.0	178.4

	Sheathing Panel		Timber (C24)																			
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**1/2 F(N)**	**F(N)**	**Ratio**	**DIN 1052-2**	**TRADA**
OSB(9mm)	550	527.1	350	341.1	1.53	9	41	495.5	31.5	15.0	0.48	434.4	941.7	278.3	181.2	396.5	193.2	115.6	231.2	0.83	203.0	190.6
Ply(9.5mm)	-	518.5	350	341.1	1.53	9.5	40.5	495.5	31.0	15.0	0.48	451.1	930.2	276.3	185.3	391.3	192.7	118.2	236.3	0.85	203.0	192.9
Cement(12)	650	622.9	350	341.1	1.53	12	38	495.5	37.3	15.0	0.40	684.5	872.8	295.4	239.7	375.9	198.2	126.4	252.8	0.84	203.0	232.4
PanelVent(9)	650	622.9	350	341.1	1.53	9	41	495.5	37.3	15.0	0.40	513.4	941.7	293.3	197.5	403.0	198.2	125.9	251.9	0.86	203.0	203.2
Fermacell(12.5)	1100	1054.2	350	341.1	1.53	12.5	37.5	495.5	63.1	15.0	0.24	1206.7	861.3	361.9	340.4	386.5	210.9	134.5	269.1	0.73	203.0	262.6
Chipboard(12)	650	622.9	350	341.1	1.53	12	38	495.5	37.3	15.0	0.40	684.5	872.8	295.4	239.7	375.9	198.2	126.4	252.8	0.84	203.0	232.4
Bitumen(12.5)	300	287.5	350	341.1	1.53	12.5	37.5	495.5	17.2	15.0	0.87	329.1	861.3	223.2	156.6	337.7	171.5	99.9	199.8	0.88	203.0	183.9

Table 3 Derivation of basic shear lateral load - KL 500 STAPLE 1.15mm wire diam, 40mm long

Fd	Kd
1.4	1.12

Category 1 & 2 Materials (excl. plasterboard)

	Sheathing Panel		Timber (C16/18/22)																	Staple/Nail		
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**1/2 F(N)**	**F(N)**	**Ratio**	**DIN 1052-2**	**TRADA**
OSB(9mm)	550	527.1	310	302.1	1.15	9	31	235.9	34.4	14.5	0.42	355.7	516.4	167.9	129.7	221.3	115.7	73.8	147.5	0.56	118.6	128.4
Ply(9.5mm)	-	518.5	310	302.1	1.15	9.5	30.5	235.9	33.8	14.5	0.43	369.4	508.1	167.5	133.5	217.7	115.4	73.6	147.2	0.57	118.6	130.9
Cement(12)	650	622.9	310	302.1	1.15	12	28	235.9	40.6	14.5	0.36	560.5	466.4	187.2	179.3	204.9	118.4	75.5	151.0	0.54	118.6	147.4
PanelVent(9)	650	622.9	310	302.1	1.15	9	31	235.9	40.6	14.5	0.36	420.4	516.4	177.9	142.9	224.7	118.4	75.5	151.0	0.55	118.6	138.8
Fermacell(12.5)	1100	1054.2	310	302.1	1.15	12.5	27.5	235.9	68.7	14.5	0.21	988.1	458.1	243.2	259.6	209.1	125.3	79.9	159.9	0.47	118.6	156
Chipboard(12)	650	622.9	310	302.1	1.15	12	28	235.9	40.6	14.5	0.36	560.5	466.4	187.2	179.3	204.9	118.4	75.5	151.0	0.54	118.6	147.4
Bitumen(12.5)	300	287.5	310	302.1	1.15	12.5	27.5	235.9	18.7	14.5	0.77	269.5	458.1	137.1	112.8	184.7	103.6	66.1	132.1	0.63	118.6	126.8

	Sheathing Panel		Timber (C24)																			
Sheathing	**ρk(20%MC)**	**ρk(15%MC)**	**ρk(20%MC)**	**ρk(15%MC)**	**d(mm)**	**t1**	**t2**	**My,d**	**fh,1,d**	**fh,2,d**	**β**	**MOF1**	**MOF2**	**MOF3**	**MOF4**	**MOF5**	**MOF6**	**1/2 F(N)**	**F(N)**	**Ratio**	**DIN 1052-2**	**TRADA**
OSB(9mm)	550	527.1	350	341.1	1.15	9	31	235.9	34.4	16.4	0.48	355.7	583.0	181.8	134.0	245.6	120.6	76.9	153.8	0.55	118.6	132.8
Ply(9.5mm)	-	518.5	350	341.1	1.15	9.5	30.5	235.9	33.8	16.4	0.48	369.4	573.6	181.1	137.8	241.6	120.3	76.7	153.4	0.55	118.6	135.4
Cement(12)	650	622.9	350	341.1	1.15	12	28	235.9	40.6	16.4	0.40	560.5	526.6	200.6	185.3	227.5	123.7	78.9	157.8	0.52	118.6	154
PanelVent(9)	650	622.9	350	341.1	1.15	9	31	235.9	40.6	16.4	0.40	420.4	583.0	192.6	147.8	249.7	123.7	78.9	157.8	0.54	118.6	143.8
Fermacell(12.5)	1100	1054.2	350	341.1	1.15	12.5	27.5	235.9	68.7	16.4	0.24	988.1	517.2	258.6	269.9	233.0	131.7	84.0	168.0	0.45	118.6	164
Chipboard(12)	650	622.9	350	341.1	1.15	12	28	235.9	40.6	16.4	0.40	560.5	526.6	200.6	185.3	227.5	123.7	78.9	157.8	0.52	118.6	154
Bitumen(12.5)	300	287.5	350	341.1	1.15	12.5	27.5	235.9	18.7	16.4	0.87	269.5	517.2	147.6	115.6	203.5	107.1	68.3	136.6	0.60	118.6	130.5