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DEPARTMENT FOR STRUCTURES
Section for Metal, Timber and Polymer Structures

Notified test laboratory NB-CPR no. 1404

Ljubljana, March 30th, 2015

REPORT

No. P 0709/14-630-3

on control laboratory tests of timber screws produced by Homn Reen Enterprise Co., Ltd. (Chipboard SS410), according to EN 14592:2008+A1:2012

Orderer :	Georgia International Certification Co. Ltd., 14F., No.26, Fengnan Rd., Fengshan Dist, Kaohsiung City 830, Taiwan
Order/contract :	Offer No. 1283/2013 from October 27th, 2013

Responsible investigator:

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1. INTRODUCTION

This report contains the results of geometry measurements and mechanical tests of timber screws in accordance with provisions of the technical specification EN 14592:2008+A1:2012 (*Timber structures - Dowel-type fasteners - Requirements*). Control measurements of geometry and tests for defining mechanical characteristics were carried out at the Laboratory for Structures of Slovenian National Building and Civil Engineering Institute (ZAG Ljubljana), Dimičeva 12, 1000 Ljubljana, from January 15th to January 30th, 2015.

2. DESCRIPTION OF TIMBER SCREWS

2.1 Definition of product

Tested screws were manufactured by Homn Reen Enterprise Group, No. 136, Lane 513, Ta Tung Rd., Luzhu Dist., Kaohsiung City 82148, Taiwan. Screws originated from two manufacturing plants:

No. 1: Homn Reen (Vietnam) Co., Ltd., Road No. 8, Tam Phuoc Industrial Zone, Bien Hoa City, Dong Nai Province, Vietnam (half of samples, marked as V),

No. 2: Homn Reen Enterprise Co, Ltd. Address: No. 136, Lane 513, Ta Tung Rd., Luzhu Dist., Kaohsiung City 82148, Taiwan (half of samples, marked as T).

The following type of screws which shall be used in timber structures was tested - their geometry is presented in Figure 1:

- Chipboard screws with nominal diameters 2.5, 3, 3.5, 4, 4.5, 5 and 6 mm (C_Flat and C_Pan head types).

According to the material specification, provided by the client, the screws were produced from the following type of material: Stainless Steel 410.

The nominal dimensions of screws are presented in Table 1.

Dimensions of screws

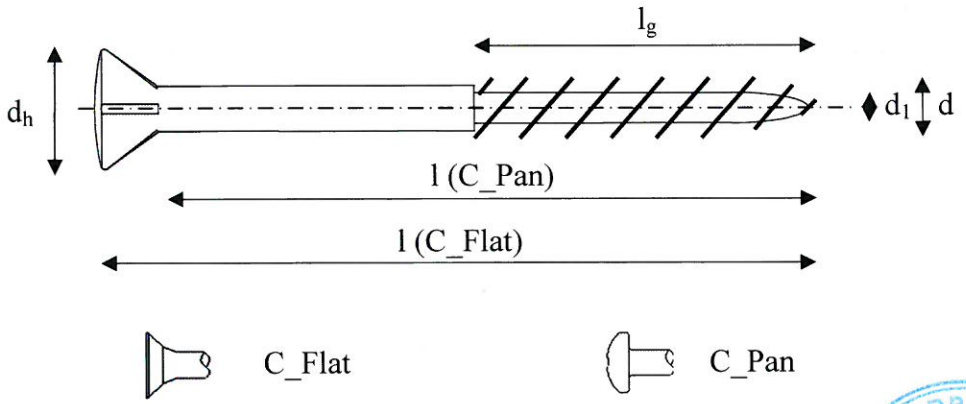

Figure 1: Geometry of screws

Table 1: Marking and grouping of screws

Mark-ing	d[1] [mm]	Head type family	l_i[2] [mm]	l[3][mm]	Characteristic yield moment	Characteristic withdrawal parameter[4]	Char. head pull-through parameter[4]	Characteristic tensile capacity	Characteristic torsional strength/resistance[4]
Chipboard screws – stainless steel SS410									
2.5	**2.43**	**C_Flat**	**5~50**	**30**	**x**	**x**	**x**	**x**	**x/x**
2.5	2.43	C_Pan	5~50	30			x	x	
3	**2.92**	**C_Flat**	**5~50**	**40**	**x**	**x**	**x**	**x**	**x/x**
3	2.92	C_Pan	5~50	40			x	x	
3.5	**3.43**	**C_Flat**	**8~70**	**40**	**x**	**x**	**x**	**x**	**x/x**
3.5	3.43	C_Pan	8~70	40			x	x	
4	**3.92**	**C_Flat**	**8~100**	**50**	**x**	**x**	**x**	**x**	**x/x**
4	3.92	C_Pan	8~100	50			x	x	
4.5	**4.47**	**C_Flat**	**10~100**	**60**	**x**	**x**	**x**	**x**	**x/x**
4.5	4.47	C_Pan	10~100	60			x	x	
5	**4.95**	**C_Flat**	**10~150**	**80**	**x**	**x**	**x**	**x**	**x/x**
5	4.95	C_Pan	10~150	80			x	x	
6	**5.93**	**C_Flat**	**10~300**	**100**	**x**	**x**	**x**	**x**	**x/x**
6	5.93	C_Pan	10~300	100			x	x	

[1] declared nominal diameter
[2] informative lengths/ threaded length
[3] declared nominal length of test specimens
[4] results taken form the ZAG report P 0709/14-630-1 on control laboratory tests of timber screws produced by Homn Reen Enterprise Co., Ltd. (Chipboard C1022), according to EN 14592:2008+A1:2012

3. STANDARD REQUIREMENTS

Geometry and mechanical characteristics of screws were evaluated according to the harmonized European standard EN 14592:2008+A1:2012, Chapters 6.3.3 and 6.3.4. Initial type testing of mechanical characteristics was performed according to the requirements given in EN 14592:2008+A1:2012, Chapter 7.2 (Table 2.3).

3.1 Geometry

Standard EN 14592:2008+A1:2012 defines the following criteria for geometry properties of the screws:

- The nominal diameter (outer thread diameter), d, used for screws shall not be less than 2.4 mm and not greater than 24 mm. The measured nominal diameter shall be within ± 2.5 % of the declared value. The minimum measurement should be taken as the nominal diameter. All other dimensions are calculated as average values.
- The inner threaded diameter of screws, d_1, shall not be less than 60 % and not more than 90 % of the outer threaded diameter, d ($0.6\ d \leq d_1 \leq 0.9\ d$).
- Screws shall be threaded over a minimum length l_g ($l_g \geq 4\ d$), the length and threaded length shall be declared. The overall length shall be within ± 2.5 % of the declared value.
- Threaded length and head diameter have to be within ± 5 % of the declared values.

Five specimens have to be sampled. Calibrated measuring device has to be capable of achieving an accuracy of ± 1 % of the measurement.

3.2 Mechanical strength and stiffness

The following mechanical characteristic have to be declared for the screws:

- Characteristic yield moment,
- Characteristic withdrawal parameter,
- Characteristic head pull through parameter,

- Characteristic tensile capacity,
- Characteristic torsional ratio.

At least ten specimens have to be tested for each diameter. Characteristic values have to be calculated according to EN 14358:2006 *(Timber structures – Calculation of characteristic 5-percentile values and acceptance criteria for a sample)*.

3.2.1 Characteristic yield moment

Characteristic yield moment $M_{y,k}$ is the minimum characteristic value determined on both the threaded section and the smooth section of the screw (in cases where this is feasible). Tests have to be performed according to EN 409:2009 *(Timber structures – Test methods – Determination of the yield moment of dowel type fasteners)*, where the bending angle α is limited to a maximum value of $45/d^{0.7}$ degrees, d in mm (Figure 2). The distances l_1 in l_3 are equal to 2d and the distance l_2 is equal to 3d. No cracks shall be observed at a bending angle α_k of less than $(45/d^{0.7} + 10)$ degrees. Test should be performed in 10 ± 5 s.

Pass/fail criteria is used for description of cracks.

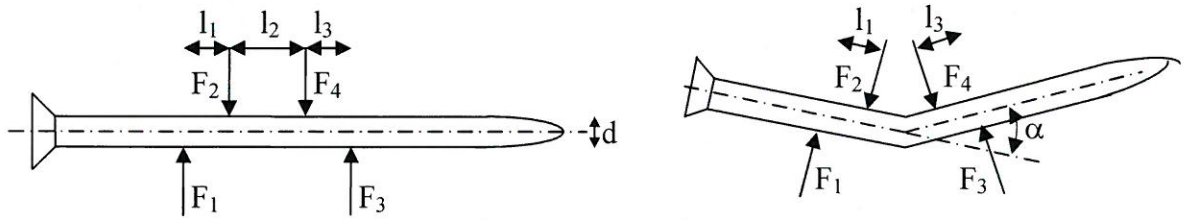

Figure 2: Schematic representation of yield moment test

3.2.2 Characteristic withdrawal parameter (perpendicular to grain)

Characteristic withdrawal parameter $f_{ax,k}$ is declared on specific timber density directly by testing in accordance with EN 1382:1999 *(Timber structures – Test methods – Withdrawal capacity of timber fasteners)*.

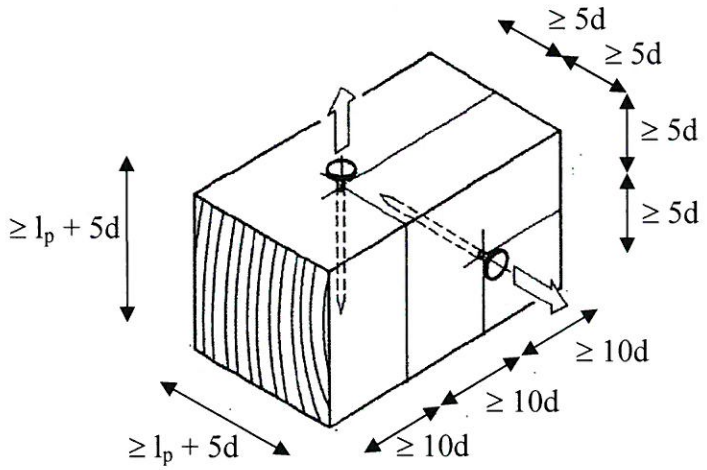

Figure 3: Schematic representation of withdrawal test (EN 1382:1999)

The screw axis should be perpendicular to the timber surface. Installation of screws should follow the manufacturer recommendations. Solid timber elements can be used; their geometry has to comply with dimensions on Figure 3.

The penetration depth l_p should be bigger than threaded length l_g. Test should be performed in 90 ± 30 s.

As a result of testing, characteristic withdrawal parameter values ($f_{ax,k} = F_{max} / (d \cdot l_p)$) together with the characteristic timber density (ρ_k) are declared.

3.2.3 Characteristic head pull through parameter

Characteristic head pull through parameter $f_{ax,k}$ is declared by testing (Figure 4) in accordance with EN 1383:1999 *(Timber structures – Test methods – Withdrawal capacity of timber fasteners)* on one timber density: screws are pull through timber pieces.

The screw axis should be perpendicular to the timber surface, knots and other imperfections should be avoided. The dimensions of timber elements are defined: the thickness (t) is less or equal to 7d and the width and length are equal to 4t.

The rate of loading shall be such that the time taken to reach F_{max} is 300 ± 30 s.

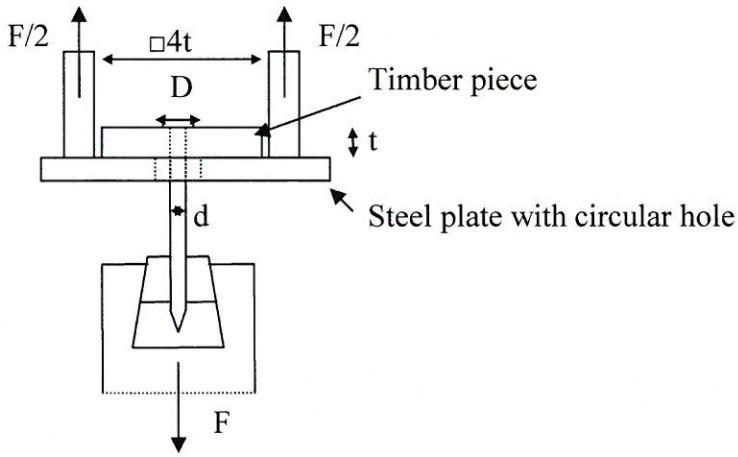

Figure 4: Schematic representation of head pull through test (EN 1383:1999)

Table 2: Dimensions of timber pieces and diameters of circular holes (diameter D)

	d* [mm]	t ≤ 7d [mm]	D [mm], D ≥ 2t
Chipboard screws	2.43	17.5	40
	2.92	21	50
	3.43	24.5	60
	3.92	28	65
	4.47	31.5	75
	4.95	35	80
	5.93	42	95

* declared nominal diameter

The pull through parameter (f) is determined from equation: $f = F_{max} / d_h^2$. As a result of testing, characteristic head pull through parameter values ($f_{head,k}$) together with the characteristic timber density (ρ_k) shall be declared.

3.2.4 Characteristic tensile capacity

Characteristic tensile capacity $f_{tens,k}$ is declared by testing in accordance with EN 1383:1999, using a steel plate to replace the head side timber member shown in Figure 4 (also see Figure 4 in standard EN 1383:1999). The steel plate shall have sufficient thickness to introduce either a pull-off failure of the head, or a tensile failure of the shank and shall contain a pre-drilled hole for the screw which may not exceed the maximum outer diameter of the screw + 1 mm in diameter. The rate of loading shall be chosen so that the failure load (ultimate load) is reached within 10 ± 30 s.

As a result of testing, tensile capacity values ($f_{tens,k}$) for each diameter are declared.

3.2.5 Characteristic torsional ratio

Characteristic torsional ratio is declared as a ratio between characteristic torsional strength ($f_{tor,k}$) and characteristic torsional resistance to insertion into timber ($R_{tor,k}$). Characteristic torsional strength shall be determined by testing in accordance with the method given in EN ISO 10666:1999, 4.2.3. Screws shall be clamped in the area of thread in such way that thread is not damaged. At least two pitches of screw thread must protrude above the clamping. The torque has to be measured with suitable calibrated torque measuring device.

Torsional resistance to insertion shall be determined by testing in accordance with the method given in EN 14592:2008, Annex B. Screws have to be screwed into the timber piece with less than 100 revolutions per minute until the screw is fully embedded along its entire length in the timber specimen. Timber with the density between 400 and 500 kg/m^3 should be used. Vertical displacement and screw insertion moment have to be recorded. By using the moment/penetration depth diagram the maximum value of the screw insertion moment ($R_{tor,\rho}$) prior to the point at which the screw head came into contact with the timber specimen. Insertion moment has to be adjusted to a common timber density of 450 kg/m^3 using the equation $R_{tor} = (450/\rho)\, R_{tor,\rho}$.

The ratio $f_{tor,k} / R_{tor,k}$ should be bigger than 1.5.

3.3 Corrosion protection

For screws where corrosion protection is required, the grade of parent material or thickness of coating material shall be declared in accordance with Annex A of EN 14592:2008+A1:2012.

4. SPECIMENS

Standard EN 14592:2008+A1:2012 in clause 7.1 allows grouping of products into families "where it is considered that the results for one or more characteristic from any one product within the family are representative for that same characteristics for all the products within that same family". Grouping of screws was performed in agreement with the client and is presented in Table 1.

Spruce structural timber corresponding to the strength class C24 (or GL 24) was used in the tests. Timber originated from Slovenia.

Specimens were delivered to ZAG laboratory on June 11th, 2014. The specimens were designated as:

- Geometry:

  L14115/G/1 – L14115/G/140,

- Yield moment test:

  L14115/A/1 – L14115/A/140,

- Tensile capacity test:

  L14115/D/1 – L14115/D/140,

- Torsional ratio:

  Torsional strength:

  L14115/F/1 – L14115/F/70.

5. MEASURING EQUIPMENT

Screws dimensions and dimensions of timber pieces (except length) were measured with the calliper gauges with accuracy ± 0.03 mm. The length of timber pieces (withdrawal parameter test, torsional resistance to insertion) was measured with the measuring tape (accuracy ± 1 mm).

The moisture content was measured according to SIST EN 13183-2:2003 *(Moisture content of a piece of sawn timber - Part 2: Estimation by electrical resistance method*). GANN 4050 measuring instrument was used.

The masses and consequently the weights of timber pieces were measured with electronic laboratory balance KERN FKB A (accuracy ± 1 g).

The displacements were measured with a linear variable differential transformers (LVDTs) with accuracy ± 0.03 mm (displacements bigger than 50 mm with accuracy ± 0.1 mm).

Forces (torque) were measured with the load cells with the following measuring range/accuracy:

- Yield moment test, withdrawal parameter test, head pull through parameter test, tensile capacity test: 50 kN ± 0.05 kN,
- Torsional strength and torsional resistance to insertion: 100 Nm ± 0.03 Nm.

6. TEST RESULTS

6.1 Geometry

The geometry of five screws for each diameter was checked. The average values of results are presented in Tables 3-4.

The following dimensions were checked:

- d – nominal diameter,
- l – overall screw length,
- l_g – threaded length,
- d_h – head diameter.

All measured dimensions satisfy the criteria given by the standard EN 14592:2008+A1:2012 (see also Chapter 3.1).

- All other standard requirements regarding the geometry of screws are fulfilled.

Table 3: Dimensions of screws - Factory No. 1 (Vietnam)

Screws-marking	Head Type	Group of specimens	d_{nom} [mm]	d_{meas} [mm]	$(d_{meas}/d_{nom}) - 1$ [%]	$d_{1,nom}$ [mm]	$d_{1,nom}/d_{nom}$	l_{nom} [mm]	l_{meas} [mm]	$(l_{meas}/l_{nom}) - 1$ [%]	$d_{h,nom}$ [mm]	$d_{h,meas}$ [mm]	$(d_{h,meas}/d_{h,nom})-1$ [%]
Factory No. 1 (Vietnam)													
2.5x30	C_Flat	L14115/G/1-5	2.43	2.49	2.47	1.60	0.64	30.00	30.34	1.12	4.90	4.86	-0.82
2.5x30	C_Pan	L14115/G/6-10	2.43	2.49	2.47	1.60	0.64	30.00	30.16	0.53	4.80	4.80	0.04
3x40	C_Flat	L14115/G/11-15	2.92	2.91	-0.34	1.80	0.60	40.00	40.01	0.03	5.80	5.78	-0.31
3x40	C_Pan	L14115/G/16-20	2.92	2.86	-2.05	1.80	0.60	40.00	40.25	0.62	5.80	5.79	-0.21
3.5x40	C_Flat	L14115/G/21-25	3.43	3.38	-1.46	2.10	0.60	40.00	40.03	0.07	6.80	6.72	-1.21
3.5x40	C_Pan	L14115/G/26-30	3.43	3.40	-0.87	2.10	0.60	40.00	39.89	-0.27	6.80	6.72	-1.21
4x50	C_Flat	L14115/G/31-35	3.92	3.86	-1.53	2.38	0.60	50.00	49.93	-0.14	7.75	7.81	0.72
4x50	C_Pan	L14115/G/36-40	3.92	3.86	-1.53	2.38	0.60	50.00	49.22	-1.56	7.75	7.81	0.72
4.5x60	C_Flat	L14115/G/41-45	4.47	4.36	-2.46	2.68	0.60	60.00	59.59	-0.69	8.70	8.85	1.77
4.5x60	C_Pan	L14115/G/46-50	4.47	4.36	-2.46	2.68	0.60	60.00	59.72	-0.47	8.70	8.73	0.32
5x80	C_Flat	L14115/G/51-55	4.95	4.83	-2.42	2.98	0.60	80.00	79.98	-0.03	9.70	9.78	0.85
5x80	C_Pan	L14115/G/56-60	4.95	4.87	-1.62	2.98	0.60	80.00	80.33	0.42	9.70	9.55	-1.55
6x100	C_Flat	L14115/G/61-65	5.93	5.79	-2.36	3.57	0.60	100.0	98.20	-1.80	11.65	11.71	0.53
6x100	C_Pan	L14115/G/66-70	5.93	5.79	-2.36	3.57	0.60	100.0	98.19	-1.81	11.65	11.65	0.03

Table 4: Dimensions of screws - Factory No. 1 (Taiwan)

Screws-marking	Head Type	Group of specimens	d_{nom} [mm]	d_{meas} [mm]	$(d_{meas}/d_{nom}) - 1$ [%]	$d_{1,nom}$ [mm]	$d_{1,nom}/d_{nom}$	l_{nom} [mm]	l_{meas} [mm]	$(l_{meas}/l_{nom}) - 1$ [%]	$d_{h,nom}$ [mm]	$d_{h,meas}$ [mm]	$(d_{h,meas}/d_{h,nom})-1$ [%]
Factory No. 1 (Taiwan)													
2.5x30	C_Flat	L14115/G/71-75	2.43	2.49	2.47	1.60	0.64	30.00	30.21	0.70	4.90	4.83	-1.39
2.5x30	C_Pan	L14115/G/76-80	2.43	2.49	2.47	1.60	0.64	30.00	30.09	0.30	4.80	4.79	-0.21
3x40	C_Flat	L14115/G/81-85	2.92	2.89	-1.03	1.80	0.60	40.00	40.01	0.03	5.80	5.77	-0.59
3x40	C_Pan	L14115/G/86-90	2.92	2.90	-0.68	1.80	0.60	40.00	40.21	0.53	5.80	5.78	-0.31
3.5x40	C_Flat	L14115/G/91-95	3.43	3.38	-1.46	2.10	0.60	40.00	40.09	0.23	6.80	6.75	-0.79
3.5x40	C_Pan	L14115/G/96-100	3.43	3.39	-1.17	2.10	0.60	40.00	39.72	-0.69	6.80	6.70	-1.41
4x50	C_Flat	L14115/G/101-105	3.92	3.84	-2.04	2.38	0.60	50.00	49.93	-0.14	7.75	7.85	1.24
4x50	C_Pan	L14115/G/106-110	3.92	3.83	-2.30	2.38	0.60	50.00	49.26	-1.48	7.75	7.81	0.83
4.5x60	C_Flat	L14115/G/111-115	4.47	4.36	-2.46	2.68	0.60	60.00	59.55	-0.75	8.70	8.86	1.84
4.5x60	C_Pan	L14115/G/116-120	4.47	4.36	-2.46	2.68	0.60	60.00	59.66	-0.57	8.70	8.73	0.39
5x80	C_Flat	L14115/G/121-125	4.95	4.85	-2.02	2.98	0.60	80.00	79.98	-0.03	9.70	9.77	0.74
5x80	C_Pan	L14115/G/126-130	4.95	4.83	-2.42	2.98	0.60	80.00	80.54	0.68	9.70	9.54	-1.69
6x100	C_Flat	L14115/G/131-135	5.93	5.79	-2.36	3.57	0.60	100.0	98.18	-1.82	11.65	11.71	0.53
6x100	C_Pan	L14115/G/136-140	5.93	5.79	-2.36	3.57	0.60	100.0	98.33	-1.67	11.65	11.67	0.17

6.2 Characteristic yield moment

Testing equipment, position of specimen and position of measuring equipment at yield moment test are presented in Figure 5.

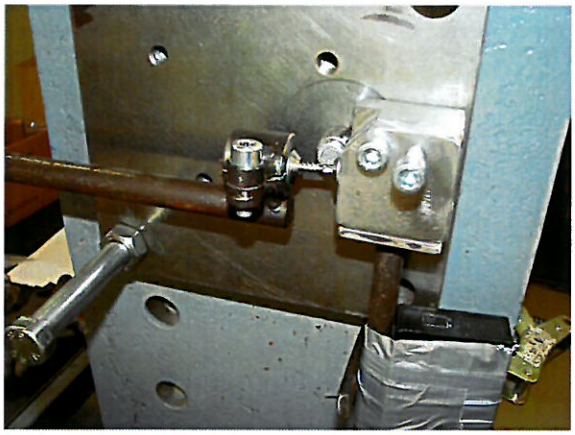

Figure 5: Yield moment test – test setup

Half of the specimens in each group were tested on threaded section and half of them on non-threaded section (in cases where this was feasible). Test results are presented in Table 5. Detailed results can be found in the Annex A.

Table 5: Characteristic yield moment – Chipboard screws

Material	Screws (marking)	Group of specimens	Bending angle α [°]	$M_{y,average}$ [Nm]	**$M_{y,k}$ [Nm]**	α_k [°]	**Presence of cracks at α_k (all specimens in group)**
SS410	**2.5x30**	**L14115/A/1-10**	**23.7**	**0.64**	**0.40**	33.7	**no cracks observed**
	3x40	L14115/A/11-20	20.9	1.21	**0.97**	30.9	**no cracks observed**
	3.5x40	**L14115/A/21-30**	**18.7**	**1.27**	**1.11**	28.7	**no cracks observed**
	4x50	L14115/A/31-40	17.1	3.75	**3.21**	27.1	**no cracks observed**
	4.5x60	**L14115/A/41-50**	**15.7**	**4.17**	**3.43**	25.7	**no cracks observed**
	5x80	L14115/A/51-60	14.6	8.68	**8.18**	24.6	**no cracks observed**
	6x100	**L14115/A/61-70**	**12.8**	**7.86**	**7.03**	22.8	**no cracks observed**

6.3 Characteristic withdrawal parameter (perpendicular to grain)

Figure 6: Withdrawal parameter test – test setup and specimens

Testing equipment and position of specimen at withdrawal parameter test are presented in Figure 6. Tests were performed on C1022 Chipboard screws.

Test results are presented in Table 6. One piece of timber was used for each test group. Penetration depth l_p used for calculation of withdrawal parameter was measured. Detailed test results can be found in the Annex A.

All screws were pulled out of timber as defined in testing procedure.

Table 6: Characteristic withdrawal parameter – Chipboard screws

Group of specimens	Screws (marking)	Nominal diameter d_{nom} [mm]	Average penetration depth l_p [mm]	ρ^* [kg/m^3]	$F_{ax,average}$ [kN]	Average withdrawal parameter $f_{ax,average}^{**}$ [N/mm^2]	**Characteristic withdrawal parameter $f_{ax,k}^{**}$ [N/mm^2]**
L14088/B/1-10	**2.5x30**	**2.43**	**26.50**	**447**	1.429	22.20	**16.50**
L14088/B/11-20	3x40	2.92	30.00	460	2.319	26.47	**21.11**
L14088/B/21-30	**3.5x40**	**3.43**	**30.00**	**486**	2.647	25.72	**23.72**
L14088/B/31-40	4x50	3.92	30.00	546	3.239	27.54	**25.36**
L14088/B/41-50	**4.5x60**	**4.47**	**45.00**	**451**	3.945	19.61	**17.31**
L14088/B/51-60	5x80	4.95	45.00	491	5.165	23.19	**22.16**
L14088/B/61-70	**6x100**	**5.93**	**50.00**	**501**	6.517	21.98	**20.66**

* Average density or density of single piece.

** Perpendicular to grain.

6.4 Characteristic head pull through parameter

Figure 7: Head pull through test – test setup and specimens

Testing equipment, position of timber and specimen at head pull through parameter test are presented in Figure 7. Test results are presented in Table 7. The nominal head diameter was used when calculating head pull through parameters. Design thickness of timber pieces was in all cases approximately seven times diameter (7d). Tests were performed on C1022 Chipboard screws.

Table 7: Average and characteristic head pull through parameters – Chipboard screws

Group of specimens	Screws (marking)	$h_{average}$ * [mm]	$\rho_{average}$ [kg/m^3]	ρ_k [kg/m^3]	$f_{head,average}$ [N/mm^2]	$f_{head,k}$ [N/mm^2]
L14088/C/1-10	**2.5x30 C_Flat**	**17.67**	**490.8**	**349.0**	**35.38**	**14.51**
L14088/C/11-20	2.5x30 C_Pan	17.67	482.9	356.4	34.04	**25.50**
L14088/C/21-30	**3x40 C_Flat**	**21.25**	**474.6**	**372.0**	**42.10**	**24.41**
L14088/C/31-40	3x40 C_Pan	21.18	470.9	353.3	36.27	**13.99**
L14088/C/41-50	**3.5x40 C_Flat**	**24.80**	**552.3**	**510.8**	**45.45**	**34.86**
L14088/C/51-60	3.5x40 C_Pan	24.78	548.7	495.9	48.19	**36.35**
L14088/C/61-70	**4x50 C_Flat**	**28.23**	**489.0**	**360.2**	**32.31**	**27.58**
L14088/C/71-80	4x50 C_Pan	28.17	487.1	364.8	31.30	**22.01**
L14088/C/81-90	**4.5x60 C_Flat**	**31.25**	**584.0**	**541.1**	**45.18**	**42.72**
L14088/C/91-100	4.5x60 C_Pan	31.37	551.2	462.1	37.15	**29.80**
L14088/C/101-110	**5x80 C_Flat**	**35.38**	**568.8**	**533.3**	**23.80**	**20.38**
L14088/C/111-120	5x80 C_Pan	35.28	566.5	539.7	37.26	**27.07**
L14088/C/121-130	**6x100 C_Flat**	**42.40**	**474.2**	**332.2**	**18.44**	**13.76**
L14088/C/131-140	6x100 C_Pan	42.41	468.4	327.6	26.08	**15.77**

* Average measured height of timber pieces ($h_{average} \leq 7d$).

Detailed results can be found in the Annex A.

In all test cases the screws were pulled through timber piece.

6.5 Characteristic tensile capacity

Testing equipment, position of specimen at tensile capacity tests are presented in Figure 8. Test results are presented in Table 8.

Detailed test results are presented in the Annex A.

Table 8: Average and characteristic tensile capacity – Chipboard

Material	Group of specimens	Screws (marking)	$f_{tens,average}$ [kN]	$f_{tens,k}$ [kN]
SS410	**L14115/D/1-10**	**2.5x30 C_Flat**	**2.61**	**2.24**
	L14115/D/11-20	2.5x30 C_Pan	2.99	**2.72**
	L14115/D/21-30	**3x40 C_Flat**	**4.02**	**3.73**
	L14115/D/31-40	3x40 C_Pan	4.02	**3.76**
	L14115/D/41-50	**3.5x40 C_Flat**	**3.97**	**3.88**
	L14115/D/51-60	3.5x40 C_Pan	4.37	**3.93**
	L14115/D/61-70	**4x50 C_Flat**	**7.16**	**6.94**
	L14115/D/71-80	4x50 C_Pan	7.36	**7.19**
	L14115/D/81-90	**4.5x60 C_Flat**	**8.53**	**8.44**
	L14115/D/91-100	4.5x60 C_Pan	7.67	**7.13**
	L14115/D/101-110	**5x80 C_Flat**	**9.96**	**9.77**
	L14115/D/111-120	5x80 C_Pan	10.61	**10.33**
	L14115/D/121-130	**6x100 C_Flat**	**12.47**	**12.34**
	L14115/D/131-140	6x100 C_Pan	12.83	**12.13**

Figure 8: Tensile capacity test – test setup and specimens

6.6 Characteristic torsional ratio

Testing equipment for performing torsional resistance to insertion test is presented in Figure 9 (tests were performed on C1022 Chipboard screws) while testing equipment and position of specimen at torsional strength test are presented in Figure 10.

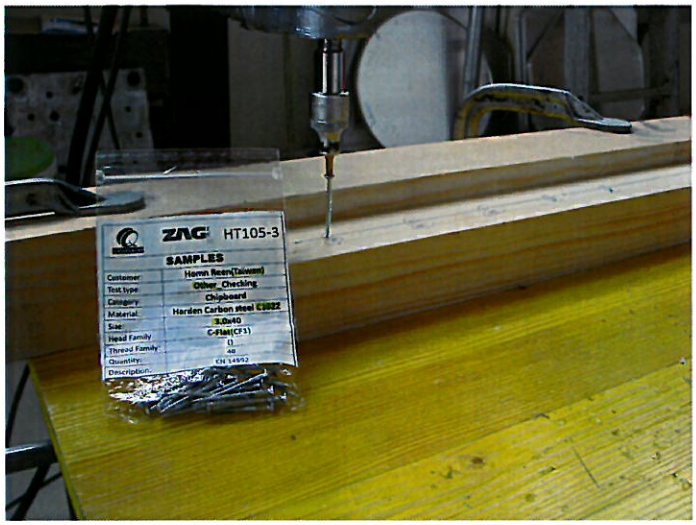

Figure 9: Torsional resistance to insertion of screws – test setup and specimens

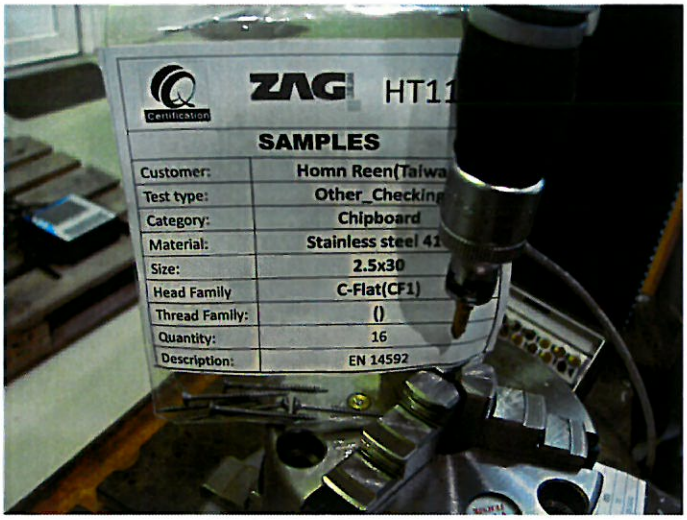

Figure 10: Torsional strength test – test setup and specimens

Table 9: Average and characteristic torsional ratio – Chipboard screws

				Torsional strength (F)		Resistance to insertion (E)			
Material	Screw (marking)	Group of specimens (F)	Group of specimens (E)	$f_{tor,average}$ [Nm]	$f_{tor,k}$ [Nm]	$R_{tor,average}$ [Nm]	$R_{tor,k}$ [Nm]	ρ [kg/m^3]	**ratio**
SS410	2.5x30	L14115/F/1-10	L14088/E/1-10	1.13	1.05	0.28	0.16	440	**6.52**
	3x40	L14115/F/11-20	L14088/E/11-20	1.92	1.87	0.25	0.20	485	**9.26**
	3.5x40	L14115/F/21-30	L14088/E/21-30	2.13	2.07	0.66	0.51	489	**4.07**
	4x50	L14115/F/31-40	L14088/E/31-40	4.01	3.96	0.86	0.71	496	**5.58**
	4.5x60	L14115/F/41-50	L14088/E/41-50	5.37	5.29	1.66	1.24	506	**4.26**
	5x80	L14115/F/51-60	L14088/E/51-60	6.80	6.33	1.86	1.72	522	**3.67**
	6x100	L14115/F/61-70	L14088/E/61-70	10.78	10.65	3.00	2.42	534	**4.40**

Separate specimens were used for torsional resistance to insertion test and torsional strength test. The first group of specimens was marked as group E and the other as F.

The results – characteristic torsional ratios – are presented in Table 9. Values of average and characteristic resistances to insertion are adjusted to the average timber density 450 kg/m^3.

The point of destruction was most commonly in the area of thread. No unexpected failures occurred in both tests.

7. Conclusions

The purpose of presented testing was to evaluate the geometry and mechanical performance of screws with the requirements defined in EN 14592:2008+A1:2012. On the basis of the measurements of geometry and on the basis of laboratory tests (yield moment test, withdrawal parameter test, head pull-through parameter test, tensile capacity test and characteristics torsional ratio tests), the following conclusions can be made:

- The dimensions of specimens comply with the requirements of EN 14592:2008+A1:2012.
- The values of characteristic yield moment $M_{y,k}$ vary in the range of 0.40 Nm to 8.18 Nm. No cracks were observed at angle α_k.
- The values of characteristic withdrawal parameter $f_{ax,k}$ vary in the range of 16.50 N/mm^2 to 25.36 N/mm^2.
- The values of characteristic head pull through parameter $f_{head,k}$ vary in the range of 13.76 N/mm^2 to 42.72 N/mm^2. Timber pieces with thickness approximately 7d were used in all test cases.
- The values of characteristic tensile capacity $f_{tens,k}$ vary in the range of 2.24 kN to 12.24 kN.
- The values of torsional ratio vary in the range of 3.56 to 7.55.

An overview of test results is given in Table 10.

Table 10: Test results – Chipboard screws

Material	Screws (marking)	d_{nom} [1] [mm]	l_{nom} [1] [mm]	$M_{y,k}$ [Nm]	$f_{ax,k}$ [2] [N/mm^2]	$f_{head,k}$ [3] [N/mm^2]	$f_{tens,k}$ [kN]	$f_{tor,k}$ / $R_{tor,k}$ [4]
SS410	2.5x30 C_Flat	2.43	5~50	0.40	16.50 (ρ = 447 kg/m^3)	14.51 (ρ_k = 349 kg/m^3)	2.24	6.52
	2.5x30 C_Pan	2.43	5~50	0.40	16.50 (ρ = 447 kg/m^3)	25.50 (ρ_k = 356 kg/m^3)	2.72	6.52
	3x40 C_Flat	2.92	5~50	0.97	21.11 (ρ = 460 kg/m^3)	24.41 (ρ_k = 372 kg/m^3)	3.73	9.26
	3x40 C_Pan	2.92	5~50	0.97	21.11 (ρ = 460 kg/m^3)	13.99 (ρ_k = 353 kg/m^3)	3.76	9.26
	3.5x40 C_Flat	3.43	8~70	1.11	23.72 (ρ = 486 kg/m^3)	34.86 (ρ_k = 511 kg/m^3)	3.88	4.07
	3.5x40 C_Pan	3.43	8~70	1.11	23.72 (ρ = 486 kg/m^3)	36.35 (ρ_k = 496 kg/m^3)	3.93	4.07
	4x50 C_Flat	3.92	8~100	3.21	25.36 (ρ = 546 kg/m^3)	27.58 (ρ_k = 360 kg/m^3)	6.94	5.58
	4x50 C_Pan	3.92	8~100	3.21	25.36 (ρ = 546 kg/m^3)	22.01 (ρ_k = 365 kg/m^3)	7.19	5.58
	4.5x60 C_Flat	4.47	10~100	3.43	17.31 (ρ = 451 kg/m^3)	42.72 (ρ_k = 541 kg/m^3)	8.44	4.26
	4.5x60 C_Pan	4.47	10~100	3.43	17.31 (ρ = 451 kg/m^3)	29.80 (ρ_k = 462 kg/m^3)	7.13	4.26
	5x80 C_Flat	4.95	10~150	8.18	22.16 (ρ = 491 kg/m^3)	20.38 (ρ_k = 533 kg/m^3)	9.77	3.67
	5x80 C_Pan	4.95	10~150	8.18	22.16 (ρ = 491 kg/m^3)	27.07 (ρ_k = 540 kg/m^3)	10.33	3.67
	6x100 C_Flat	5.93	10~300	7.03	20.66 (ρ = 501 kg/m^3)	13.76 (ρ_k = 332 kg/m^3)	12.34	4.40
	6x100 C_Pan	5.93	10~300	7.03	20.66 (ρ = 501 kg/m^3)	15.77 (ρ_k = 328 kg/m^3)	12.13	4.40

[1] Diameter / length defined by manufacturer.

[2] Single piece of timber (or average). Perpendicular to grain.

[3] Thickness of timber pieces equal to 7d.

[4] Adjusted to average timber density 450 kg/m^3.

Therefore it can be concluded that geometry and mechanical characteristics of tested screws meet the initial type testing requirements defined in EN 14592:2008+A1:2012.

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ANNEX A:

DETAILED TEST RESULTS

Table A1: Characteristic yield moment – detailed test results (1/2)

Specimen	$M_{y,i}$ [Nm]	Specimen	$M_{y,i}$ [Nm]	Specimen	$M_{y,i}$ [Nm]
L14115/A/1	/	L14115/A/11	0.99	L14115/A/21	1.38
L14115/A/2	0.72	L14115/A/12	1.13	L14115/A/22	1.27
L14115/A/3	0.52	L14115/A/13	1.25	L14115/A/23	1.28
L14115/A/4	0.53	L14115/A/14	1.12	L14115/A/24	1.31
L14115/A/5	0.73	L14115/A/15	1.28	L14115/A/25	1.31
L14115/A/6	0.95	L14115/A/16	1.36	L14115/A/26	1.35
L14115/A/7	0.51	L14115/A/17	1.35	L14115/A/27	1.17
L14115/A/8	0.53	L14115/A/18	/	L14115/A/28	1.17
L14115/A/9	0.60	L14115/A/19	1.18	L14115/A/29	1.18
L14115/A/10	0.64	L14115/A/20	1.21	L14115/A/30	1.27
$M_{y,average}$ [Nm]	**0.64**	$M_{y,average}$ [Nm]	**1.21**	$M_{y,average}$ [Nm]	**1.27**
$M_{y,k}$ [Nm]	**0.40**	$M_{y,k}$ [Nm]	**0.97**	$M_{y,k}$ [Nm]	**1.11**

Specimen	$M_{y,i}$ [Nm]	Specimen	$M_{y,i}$ [Nm]	Specimen	$M_{y,i}$ [Nm]
L14115/A/31	3.42	L14115/A/41	4.59	L14115/A/51	8.53
L14115/A/32	4.18	L14115/A/42	4.22	L14115/A/52	8.64
L14115/A/33	3.92	L14115/A/43	4.18	L14115/A/53	8.95
L14115/A/34	4.01	L14115/A/44	/	L14115/A/54	8.52
L14115/A/35	3.67	L14115/A/45	4.23	L14115/A/55	8.77
L14115/A/36	3.63	L14115/A/46	4.10	L14115/A/56	8.56
L14115/A/37	3.95	L14115/A/47	4.33	L14115/A/57	9.07
L14115/A/38	3.49	L14115/A/48	3.33	L14115/A/58	8.80
L14115/A/39	3.45	L14115/A/49	4.38	L14115/A/59	8.28
L14115/A/40	3.75	L14115/A/50	4.17	L14115/A/60	8.68
$M_{y,average}$ [Nm]	**3.75**	$M_{y,average}$ [Nm]	**4.17**	$M_{y,average}$ [Nm]	**8.68**
$M_{y,k}$ [Nm]	**3.21**	$M_{y,k}$ [Nm]	**3.43**	$M_{y,k}$ [Nm]	**8.18**

Table A1: Characteristic yield moment – detailed test results (2/2)

Specimen	$M_{y,i}$ [Nm]
L14115/A/71	8.54
L14115/A/72	8.39
L14115/A/73	7.45
L14115/A/74	7.56
L14115/A/75	7.42
L14115/A/76	7.73
L14115/A/77	8.14
L14115/A/78	7.57
L14115/A/79	7.91
L14115/A/80	7.86
$M_{y,average}$ [Nm]	**7.86**
$M_{y,k}$ [Nm]	**7.03**

Table A2: Characteristic withdrawal parameter (1/2)

Specimen	$f_{ax,i}$ [N/mm^2]	Specimen	$f_{ax,i}$ [N/mm^2]	Specimen	$f_{ax,i}$ [N/mm^2]
L14088/B/1	20.31	L14088/B/11	30.96	L14088/B/21	26.12
L14088/B/2	17.28	L14088/B/12	25.76	L14088/B/22	26.92
L14088/B/3	19.02	L14088/B/13	26.62	L14088/B/23	26.38
L14088/B/4	20.59	L14088/B/14	26.70	L14088/B/24	24.42
L14088/B/5	22.27	L14088/B/15	22.98	L14088/B/25	26.59
L14088/B/6	27.49	L14088/B/16	31.19	L14088/B/26	25.89
L14088/B/7	24.96	L14088/B/17	27.15	L14088/B/27	26.35
L14088/B/8	24.33	L14088/B/18	24.50	L14088/B/28	23.92
L14088/B/9	23.23	L14088/B/19	25.95	L14088/B/29	25.20
L14088/B/10	22.47	L14088/B/20	22.91	L14088/B/30	25.45
$f_{ax,average}$ [N/mm^2]	**22.20**	$f_{ax,average}$ [N/mm^2]	**26.47**	$f_{ax,average}$ [N/mm^2]	**25.72**
$f_{ax,k}$ [N/mm^2]	**16.50**	$f_{ax,k}$ [N/mm^2]	**21.11**	$f_{ax,k}$ [N/mm^2]	**23.72**

Table A2: Characteristic withdrawal parameter (2/2)

Specimen	$f_{ax,i}$ [N/mm^2]	Specimen	$f_{ax,i}$ [N/mm^2]	Specimen	$f_{ax,i}$ [N/mm^2]
L14088/B/31	29.99	L14088/B/41	19.37	L14088/B/51	23.30
L14088/B/32	28.44	L14088/B/42	17.99	L14088/B/52	22.62
L14088/B/33	27.70	L14088/B/43	22.00	L14088/B/53	22.74
L14088/B/34	27.62	L14088/B/44	19.46	L14088/B/54	22.40
L14088/B/35	27.80	L14088/B/45	19.64	L14088/B/55	23.46
L14088/B/36	27.15	L14088/B/46	21.11	L14088/B/56	23.23
L14088/B/37	26.39	L14088/B/47	19.50	L14088/B/57	23.61
L14088/B/38	26.31	L14088/B/48	19.16	L14088/B/58	23.91
L14088/B/39	27.35	L14088/B/49	19.51	L14088/B/59	23.68
L14088/B/40	26.65	L14088/B/50	18.39	L14088/B/60	22.91
$f_{ax,average}$ [N/mm^2]	**27.54**	$f_{ax,average}$ [N/mm^2]	**19.61**	$f_{ax,average}$ [N/mm^2]	**23.19**
$f_{ax,k}$ [N/mm^2]	**25.36**	$f_{ax,k}$ [N/mm^2]	**17.31**	$f_{ax,k}$ [N/mm^2]	**22.16**

Specimen	$f_{ax,i}$ [N/mm^2]
L14088/B/61	22.41
L14088/B/62	22.56
L14088/B/63	22.90
L14088/B/64	21.96
L14088/B/65	22.76
L14088/B/66	21.58
L14088/B/67	21.50
L14088/B/68	21.27
L14088/B/69	21.06
L14088/B/70	21.80
$f_{ax,average}$ [N/mm^2]	**21.98**
$f_{ax,k}$ [N/mm^2]	**20.66**

Table A3: Characteristic head pull through parameter – detailed test results (1/3)

Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]
L14088/C/1	23.74	L14088/C/11	28.74	L14088/C/21	32.85
L14088/C/2	20.05	L14088/C/12	34.05	L14088/C/22	33.20
L14088/C/3	22.74	L14088/C/13	34.69	L14088/C/23	31.42
L14088/C/4	27.78	L14088/C/14	30.35	L14088/C/24	33.83
L14088/C/5	22.53	L14088/C/15	30.48	L14088/C/25	32.40
L14088/C/6	43.84	L14088/C/16	34.39	L14088/C/26	54.37
L14088/C/7	52.73	L14088/C/17	42.13	L14088/C/27	50.09
L14088/C/8	45.70	L14088/C/18	42.51	L14088/C/28	45.63
L14088/C/9	56.03	L14088/C/19	31.08	L14088/C/29	58.98
L14088/C/10	38.63	L14088/C/20	32.01	L14088/C/30	48.19
$f_{head,average}$ [N/mm^2]	**35.38**	$f_{head,average}$ [N/mm^2]	**34.04**	$f_{head,average}$ [N/mm^2]	**42.10**
$f_{head,k}$ [N/mm^2]	**14.51**	$f_{head,k}$ [N/mm^2]	**25.50**	$f_{head,k}$ [N/mm^2]	**24.41**

Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]
L14088/C/31	21.34	L14088/C/41	54.35	L14088/C/51	49.20
L14088/C/32	23.81	L14088/C/42	44.57	L14088/C/52	45.13
L14088/C/33	20.87	L14088/C/43	45.24	L14088/C/53	34.32
L14088/C/34	24.20	L14088/C/44	45.18	L14088/C/54	55.02
L14088/C/35	23.42	L14088/C/45	50.95	L14088/C/55	46.17
L14088/C/36	47.47	L14088/C/46	45.93	L14088/C/56	48.62
L14088/C/37	51.87	L14088/C/47	46.65	L14088/C/57	52.75
L14088/C/38	51.69	L14088/C/48	47.88	L14088/C/58	50.32
L14088/C/39	50.06	L14088/C/49	36.74	L14088/C/59	48.59
L14088/C/40	47.92	L14088/C/50	36.96	L14088/C/60	51.75
$f_{head,average}$ [N/mm^2]	**36.27**	$f_{head,average}$ [N/mm^2]	**45.45**	$f_{head,average}$ [N/mm^2]	**48.19**
$f_{head,k}$ [N/mm^2]	**13.99**	$f_{head,k}$ [N/mm^2]	**34.86**	$f_{head,k}$ [N/mm^2]	**36.35**

Table A3: Characteristic head pull through parameter – detailed test results (2/3)

Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]
L14088/C/61	31.28	L14088/C/71	32.18	L14088/C/81	46.06
L14088/C/62	29.59	L14088/C/72	24.79	L14088/C/82	45.87
L14088/C/63	30.52	L14088/C/73	23.91	L14088/C/83	46.02
L14088/C/64	29.09	L14088/C/74	27.44	L14088/C/84	44.13
L14088/C/65	31.20	L14088/C/75	28.55	L14088/C/85	42.86
L14088/C/66	34.10	L14088/C/76	32.77	L14088/C/86	46.15
L14088/C/67	32.77	L14088/C/77	33.98	L14088/C/87	45.30
L14088/C/68	35.41	L14088/C/78	36.35	L14088/C/88	44.15
L14088/C/69	32.88	L14088/C/79	34.38	L14088/C/89	46.57
L14088/C/70	36.31	L14088/C/80	38.66	L14088/C/90	44.66
$f_{head,average}$ [N/mm^2]	**32.31**	$f_{head,average}$ [N/mm^2]	**31.30**	$f_{head,average}$ [N/mm^2]	**45.18**
$f_{head,k}$ [N/mm^2]	**27.58**	$f_{head,k}$ [N/mm^2]	**22.01**	$f_{head,k}$ [N/mm^2]	**42.72**

Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]	Specimen	$f_{head,i}$ [N/mm^2]
L14088/C/91	31.10	L14088/C/101	22.87	L14088/C/111	30.24
L14088/C/92	30.52	L14088/C/102	22.61	L14088/C/112	32.73
L14088/C/93	38.88	L14088/C/103	23.98	L14088/C/113	33.02
L14088/C/94	39.13	L14088/C/104	22.33	L14088/C/114	35.10
L14088/C/95	38.54	L14088/C/105	22.38	L14088/C/115	32.82
L14088/C/96	39.12	L14088/C/106	23.66	L14088/C/116	36.83
L14088/C/97	36.40	L14088/C/107	27.28	L14088/C/117	41.31
L14088/C/98	36.64	L14088/C/108	26.39	L14088/C/118	40.01
L14088/C/99	40.40	L14088/C/109	22.09	L14088/C/119	48.84
L14088/C/100	40.78	L14088/C/110	24.41	L14088/C/120	41.74
$f_{head,average}$ [N/mm^2]	**37.15**	$f_{head,average}$ [N/mm^2]	**23.80**	$f_{head,average}$ [N/mm^2]	**37.26**
$f_{head,k}$ [N/mm^2]	**29.80**	$f_{head,k}$ [N/mm^2]	**20.38**	$f_{head,k}$ [N/mm^2]	**27.07**

Table A3: Characteristic head pull through parameter – detailed test results (3/3)

Specimen	$f_{head,i}$ [N/mm²]	Specimen	$f_{head,i}$ [N/mm²]
L14088/C/121	19.72	L14088/C/131	33.28
L14088/C/122	18.96	L14088/C/132	32.09
L14088/C/123	20.11	L14088/C/133	32.01
L14088/C/124	23.34	L14088/C/134	31.53
L14088/C/125	18.32	L14088/C/135	26.16
L14088/C/126	17.79	L14088/C/136	21.69
L14088/C/127	18.63	L14088/C/137	20.87
L14088/C/128	17.48	L14088/C/138	25.52
L14088/C/129	15.84	L14088/C/139	19.05
L14088/C/130	14.15	L14088/C/140	18.64
$f_{head,average}$ [N/mm²]	**18.44**	$f_{head,average}$ [N/mm²]	**26.08**
$f_{head,k}$ [N/mm²]	**13.76**	$f_{head,k}$ [N/mm²]	**15.77**

Table A4: Characteristic tensile capacity – detailed test results (1/3)

Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]
L14115/D/1	2.85	L14115/D/11	3.02	L14115/D/21	3.91
L14115/D/2	2.61	L14115/D/12	3.03	L14115/D/22	3.95
L14115/D/3	2.78	L14115/D/13	3.00	L14115/D/23	4.12
L14115/D/4	2.75	L14115/D/14	2.95	L14115/D/24	3.94
L14115/D/5	2.21	L14115/D/15	3.02	L14115/D/25	4.13
L14115/D/6	2.64	L14115/D/16	2.64	L14115/D/26	3.72
L14115/D/7	2.53	L14115/D/17	3.04	L14115/D/27	4.12
L14115/D/8	2.71	L14115/D/18	3.08	L14115/D/28	4.10
L14115/D/9	2.53	L14115/D/19	3.01	L14115/D/29	4.14
L14115/D/10	2.50	L14115/D/20	3.07	L14115/D/30	4.10
$f_{tens,average}$ [kN]	**2.61**	$f_{tens,average}$ [kN]	**2.99**	$f_{tens,average}$ [kN]	**4.02**
$f_{tens,k}$ [kN]	**2.24**	$f_{tens,k}$ [kN]	**2.72**	$f_{tens,k}$ [kN]	**3.73**

Table A4: Characteristic tensile capacity – detailed test results (2/3)

Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]
L14115/D/31	4.08	L14115/D/41	3.97	L14115/D/51	4.55
L14115/D/32	4.09	L14115/D/42	3.98	L14115/D/52	4.42
L14115/D/33	4.01	L14115/D/43	4.02	L14115/D/53	4.62
L14115/D/34	4.10	L14115/D/44	4.03	L14115/D/54	4.61
L14115/D/35	4.02	L14115/D/45	4.00	L14115/D/55	4.35
L14115/D/36	4.03	L14115/D/46	3.96	L14115/D/56	4.32
L14115/D/37	3.98	L14115/D/47	3.93	L14115/D/57	4.43
L14115/D/38	3.69	L14115/D/48	3.91	L14115/D/58	4.38
L14115/D/39	4.10	L14115/D/49	3.92	L14115/D/59	4.06
L14115/D/40	4.10	L14115/D/50	3.97	L14115/D/60	3.98
$f_{tens,average}$ [kN]	**4.02**	$f_{tens,average}$ [kN]	**3.97**	$f_{tens,average}$ [kN]	**4.37**
$f_{tens,k}$ [kN]	**3.76**	$f_{tens,k}$ [kN]	**3.88**	$f_{tens,k}$ [kN]	**3.93**

Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]
L14115/D/61	7.19	L14115/D/71	7.42	L14115/D/81	8.54
L14115/D/62	7.30	L14115/D/72	7.41	L14115/D/82	8.60
L14115/D/63	7.28	L14115/D/73	7.21	L14115/D/83	8.54
L14115/D/64	7.15	L14115/D/74	7.43	L14115/D/84	8.57
L14115/D/65	7.00	L14115/D/75	7.29	L14115/D/85	8.47
L14115/D/66	7.29	L14115/D/76	7.37	L14115/D/86	8.52
L14115/D/67	7.21	L14115/D/77	7.45	L14115/D/87	8.58
L14115/D/68	7.04	L14115/D/78	7.33	L14115/D/88	8.52
L14115/D/69	7.10	L14115/D/79	7.43	L14115/D/89	8.45
L14115/D/70	7.05	L14115/D/80	7.28	L14115/D/90	8.54
$f_{tens,average}$ [kN]	**7.16**	$f_{tens,average}$ [kN]	**7.36**	$f_{tens,average}$ [kN]	**8.53**
$f_{tens,k}$ [kN]	**6.94**	$f_{tens,k}$ [kN]	**7.19**	$f_{tens,k}$ [kN]	**8.44**

Table A4: Characteristic tensile capacity – detailed test results (3/3)

Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]
L14115/D/91	6.99	L14115/D/101	9.91	L14115/D/111	10.61
L14115/D/92	7.73	L14115/D/102	9.83	L14115/D/112	10.81
L14115/D/93	7.72	L14115/D/103	9.93	L14115/D/113	10.74
L14115/D/94	7.76	L14115/D/104	9.91	L14115/D/114	10.69
L14115/D/95	7.67	L14115/D/105	9.93	L14115/D/115	10.56
L14115/D/96	7.97	L14115/D/106	10.08	L14115/D/116	10.73
L14115/D/97	7.83	L14115/D/107	10.09	L14115/D/117	10.59
L14115/D/98	7.74	L14115/D/108	9.96	L14115/D/118	10.44
L14115/D/99	7.73	L14115/D/109	10.08	L14115/D/119	10.39
L14115/D/100	7.61	L14115/D/110	9.89	L14115/D/120	10.52
$f_{tens,average}$ [kN]	**7.67**	$f_{tens,average}$ [kN]	**9.96**	$f_{tens,average}$ [kN]	**10.61**
$f_{tens,k}$ [kN]	**7.13**	$f_{tens,k}$ [kN]	**9.77**	$f_{tens,k}$ [kN]	**10.33**

Specimen	$f_{tens,i}$ [kN]	Specimen	$f_{tens,i}$ [kN]
L14115/D/121	12.37	L14115/D/131	13.06
L14115/D/122	12.48	L14115/D/132	12.52
L14115/D/123	12.52	L14115/D/133	13.02
L14115/D/124	12.53	L14115/D/134	13.02
L14115/D/125	12.55	L14115/D/135	12.27
L14115/D/126	12.54	L14115/D/136	13.03
L14115/D/127	12.41	L14115/D/137	13.09
L14115/D/128	12.52	L14115/D/138	13.04
L14115/D/129	12.42	L14115/D/139	12.97
L14115/D/130	12.41	L14115/D/140	12.26
$f_{tens,average}$ [kN]	**12.47**	$f_{tens,average}$ [kN]	**12.83**
$f_{tens,k}$ [kN]	**12.34**	$f_{tens,k}$ [kN]	**12.13**

Table A5: Resistance to insertion test – detailed test results (1/2)

Specimen	$R_{tor,i}$ [Nm]	Specimen	$R_{tor,i}$ [Nm]	Specimen	$R_{tor,i}$ [Nm]
L14088/E/1	0.25	L14088/E/11	0.28	L14088/E/21	0.75
L14088/E/2	0.32	L14088/E/12	0.23	L14088/E/22	0.64
L14088/E/3	0.33	L14088/E/13	0.26	L14088/E/23	0.54
L14088/E/4	0.43	L14088/E/14	0.23	L14088/E/24	0.79
L14088/E/5	0.28	L14088/E/15	0.21	L14088/E/25	0.64
L14088/E/6	0.29	L14088/E/16	0.26	L14088/E/26	0.66
L14088/E/7	0.18	L14088/E/17	0.25	L14088/E/27	0.71
L14088/E/8	0.25	L14088/E/18	0.25	L14088/E/28	0.72
L14088/E/9	0.27	L14088/E/19	0.26	L14088/E/29	0.55
L14088/E/10	0.20	L14088/E/20	0.30	L14088/E/30	0.64
$R_{tor,average}$ [Nm]	**0.28**	$R_{tor,average}$ [Nm]	**0.25**	$R_{tens,average}$ [kN]	**0.66**
$R_{tor,k}$ [Nm]	**0.16**	$R_{tor,k}$ [Nm]	**0.20**	$R_{tens,k}$ [kN]	**0.51**

Specimen	$R_{tor,i}$ [Nm]	Specimen	$R_{tor,i}$ [Nm]	Specimen	$R_{tor,i}$ [Nm]
L14088/E/31	0.77	L14088/E/41	1.31	L14088/E/51	1.92
L14088/E/32	0.90	L14088/E/42	1.75	L14088/E/52	1.80
L14088/E/33	0.78	L14088/E/43	1.78	L14088/E/53	1.84
L14088/E/34	1.05	L14088/E/44	1.85	L14088/E/54	1.86
L14088/E/35	0.80	L14088/E/45	1.48	L14088/E/55	1.92
L14088/E/36	0.87	L14088/E/46	1.55	L14088/E/56	1.74
L14088/E/37	0.82	L14088/E/47	1.62	L14088/E/57	1.80
L14088/E/38	0.94	L14088/E/48	1.90	L14088/E/58	1.94
L14088/E/39	0.85	L14088/E/49	1.95	L14088/E/59	1.86
L14088/E/40	0.85	L14088/E/50	1.41	L14088/E/60	1.93
$R_{tor,average}$ [Nm]	**0.86**	$R_{tor,average}$ [Nm]	**1.66**	$R_{tens,average}$ [kN]	**1.86**
$R_{tor,k}$ [Nm]	**0.71**	$R_{tor,k}$ [Nm]	**1.24**	$R_{tens,k}$ [kN]	**1.72**

Table A5: Resistance to insertion test – detailed test results (2/2)

Specimen	$R_{tor,i}$ [Nm]
L14088/E/61	2.63
L14088/E/62	3.16
L14088/E/63	2.69
L14088/E/64	3.01
L14088/E/65	2.98
L14088/E/66	3.72
L14088/E/67	2.90
L14088/E/68	2.83
L14088/E/69	2.86
L14088/E/70	3.24
$R_{tor,average}$ [Nm]	**3.00**
$R_{tor,k}$ [Nm]	**2.42**

Table A6: Torsional strength test – detailed test results (1/2)

Specimen	$f_{tor,i}$ [Nm]	Specimen	$f_{tor,i}$ [Nm]	Specimen	$f_{tor,i}$ [Nm]
L14115/F/1	1.05	L14115/F/11	1.90	L14115/F/21	2.15
L14115/F/2	1.09	L14115/F/12	1.93	L14115/F/22	2.12
L14115/F/3	1.16	L14115/F/13	1.94	L14115/F/23	2.13
L14115/F/4	1.11	L14115/F/14	1.89	L14115/F/24	2.15
L14115/F/5	1.13	L14115/F/15	1.95	L14115/F/25	2.15
L14115/F/6	1.13	L14115/F/16	1.90	L14115/F/26	2.10
L14115/F/7	1.17	L14115/F/17	1.90	L14115/F/27	2.15
L14115/F/8	1.12	L14115/F/18	1.92	L14115/F/28	2.10
L14115/F/9	1.13	L14115/F/19	1.93	L14115/F/29	2.08
L14115/F/10	1.15	L14115/F/20	1.91	L14115/F/30	2.12
$f_{tor,average}$ [Nm]	**1.13**	$f_{tor,average}$ [Nm]	**1.92**	$f_{tor,average}$ [Nm]	**2.13**
$f_{tor,k}$ [Nm]	**1.05**	$f_{tor,k}$ [Nm]	**1.87**	$f_{tor,k}$ [Nm]	**2.07**

Table A6: Torsional strength test – detailed test results (2/2)

Specimen	$f_{tor,i}$ [Nm]	Specimen	$f_{tor,i}$ [Nm]	Specimen	$f_{tor,i}$ [Nm]
L14115/F/31	4.03	L14115/F/41	5.37	L14115/F/51	7.21
L14115/F/32	4.02	L14115/F/42	5.43	L14115/F/52	7.27
L14115/F/33	3.98	L14115/F/43	5.38	L14115/F/53	6.74
L14115/F/34	4.04	L14115/F/44	5.37	L14115/F/54	6.73
L14115/F/35	3.98	L14115/F/45	5.43	L14115/F/55	6.70
L14115/F/36	4.04	L14115/F/46	5.31	L14115/F/56	6.71
L14115/F/37	3.99	L14115/F/47	5.32	L14115/F/57	6.67
L14115/F/38	3.99	L14115/F/48	5.38	L14115/F/58	6.69
L14115/F/39	4.05	L14115/F/49	5.38	L14115/F/59	6.71
L14115/F/40	4.02	L14115/F/50	5.34	L14115/F/60	6.56
$f_{tor,average}$ [Nm]	**4.01**	$f_{tor,average}$ [Nm]	**5.37**	$f_{tor,average}$ [Nm]	**6.80**
$f_{tor,k}$ [Nm]	**3.96**	$f_{tor,k}$ [Nm]	**5.29**	$f_{tor,k}$ [Nm]	**6.33**

Specimen	$f_{tor,i}$ [Nm]
L14115/F/61	10.81
L14115/F/62	10.76
L14115/F/63	10.85
L14115/F/64	10.82
L14115/F/65	10.85
L14115/F/66	10.78
L14115/F/67	10.71
L14115/F/68	10.71
L14115/F/69	10.79
L14115/F/70	10.69
$f_{tor,average}$ [Nm]	**10.78**
$f_{tor,k}$ [Nm]	**10.65**