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REPORT

No. P 1192/11-640-1

on control laboratory tests of timber screws NW51, produced by Tecfi S.p.A, according to EN 14592:2008

Orderer :	TECFI S.p.A., S.S. Appia Km. 193, 81050 Pastorano (CE), Italy
Order/contract :	Offer No. 1040/2011 from October 5th, 2011

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1. INTRODUCTION

This report contains the results of mechanical tests of timber screws NW51 in accordance with provisions of the technical specification EN 14592:2008 (*Timber structures - Dowel-type fasteners - Requirements*). Control measurements of geometry and as well as 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 12th of December to 27th of December 2011.

This report contains test results and photographs of tests. The detailed test results and relevant diagrams are enclosed in Annexes A and B.

2. DESCRIPTION OF TIMBER SCREWS

2.1 Definition of product

Tecfi NW51 screws are self tapping hex shank dual thread screws used for solar system fixing. Screws with diameter 8, 10 and 12 mm are – according to the manufacturer documentation delivered on 19th October – produced from stainless steel SUS 304 according to JIS G4308. The geometry of screw is presented in Figure 1.

Screws shall be screwed into timber without pre-drilling.

Nominal dimensions of screws are presented in Table 1.

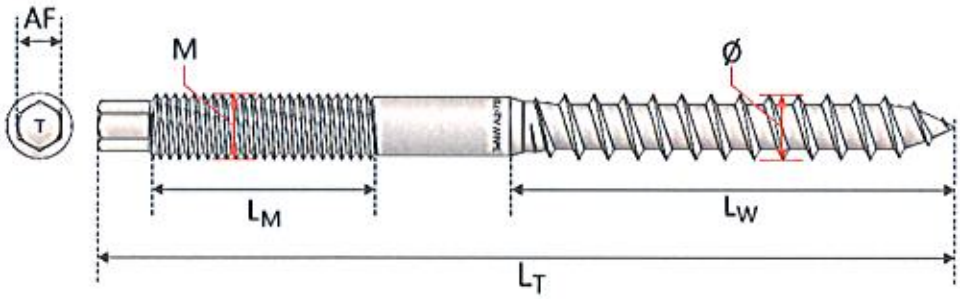

Figure 1: NW51 screws – geometry as defined in manufacturer catalogue

Table 1: NW51 screws – nominal geometry of specimens and grouping of screws

O = d [mm]	L_T = l [mm]	L_W = l_g [mm]	Characteristic yield moment test	Characteristic withdrawal parameter	Characteristic Tensile strength	Characteristic torsional ratio
8	150	65				
8	200	65	group	group	group	group
10	160	70				
10	200	70				
10	250	70				
10	300	70	group	group	group	group
12	200	80		single		single
12	250	100				
12	300	100				
12	350	100				
12	400	100	group	group	group	group

3 STANDARD REQUIREMENTS

Geometry and mechanical characteristics of NW51 screws were evaluated according to the harmonized European standard EN 14592:2008, chapter 6.3.3 and 6.4.3. Initial type testing of mechanical characteristics was performed according to the requirements given in EN 14592:2008, chapter 7.2. Tested screws – due to their purpose – differ from classical timber screws defined in EN 14592:2008. Therefore only relevant dimensions for fixation into timber were checked. Furthermore only three mechanical tests were performed: yield moment test, characteristic withdrawal parameter and characteristic torsional ratio test. Head pull through parameter test was not performed since the results would be irrelevant for the intended use of screws. Test of tensile strength of screws was additionally performed.

3.1 Geometry

Standard EN 14592:2008 defines the following criteria for geometry properties of 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 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 ($l_g \geq 6$ d), 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

Ten specimens have to be tested for each diameter in each test. 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. In addition 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.

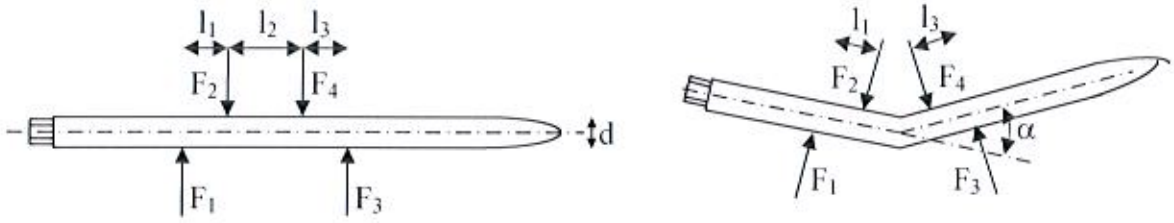

Figure 2: Schematic representation of yield moment test

3.2.2 Characteristic withdrawal parameter

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

The target value of timber density is 350 kg/m^3. The screw axis should be perpendicular to the timber surface. Installation of screws should follow the manufacturer recommendations and should comply with Figure 3.

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

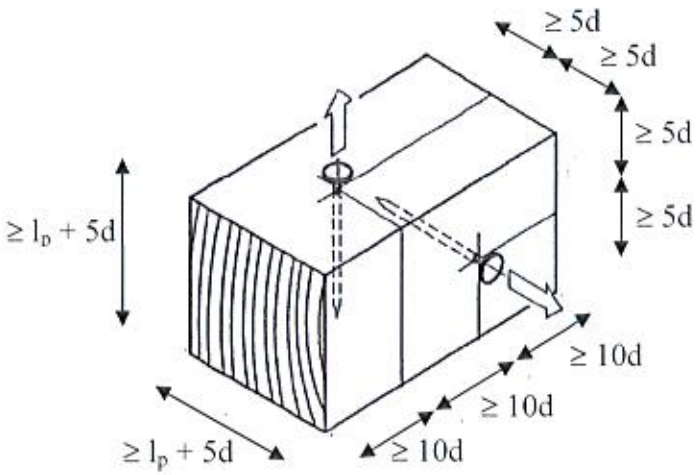

Figure 3: Schematic representation of withdrawal test (EN 1382:1999)

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

3.2.3 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. Screw 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.

3.2.4 Characteristic tensile strength

Characteristic tensile strength $f_{t,k}$ is declared by classic tensile test of screws. The rate of loading shall be chosen so that the failure load (ultimate load) is reached within 10 ± 30 s.

The result of tests are declared characteristic head pull through parameter values ($f_{t,k}$) for each diameter.

4 SPECIMENS

Standard EN 14592:2008 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 manufacturer.

Specimens were delivered to ZAG laboratory on 24th of October 2011. The screws were designated as:

- Yield moment test:

  L11094/A[diameter]_[length]/1 – L11094/A[diameter]_[length]/10,
- Withdrawal parameter test:

  L11094/C[diameter]_[length]/1 – L11094/C[diameter]_[length]/10,
- Torsional ratio:

  Torsional strength:

  L11094/B[diameter]_[length]/1 – L11094/B[diameter]_[length]/10,

  Torsional resistance to insertion:

  L11094/BR[diameter]_[length]/1 – L11094/BR[diameter]_[length]/10,
- Tensile strength test:

  L11094/D[diameter]_[length]/1 – L11094/D[diameter]_[length]/10.

5 MEASURING EQUIPMENT

Screws dimensions and dimensions of timber pieces (except length) were measured with calliper gauges with accuracy ± 0.03 mm. Length of timber pieces (withdrawal parameter test, torsional resistance to insertion) was measured with 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 mass and consequently the weight of timber pieces were measured with electronic laboratory balance KERN FKB A (accuracy ± 6 g).

The displacements were measured with linear variable differential transformers (LVDTs) with accuracy ± 0.03 mm (displacement 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 strength 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 in each group was checked. The average values of results are presented in Table 2.

The following dimensions were checked:

- d – diameter of timber threaded part,
- d_1 – inner threaded diameter of screws,
- l – overall screw length,
- l_g – threaded length,
- d_{nt} – diameter (non threaded),
- a_{head} – hexagonal head dimension.

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

Table 2: Dimensions of screws

nominal d/l/l_g	d [mm]	d_1 [mm]	l [mm]	l_g [mm]	d_{nt} [mm]	a_{head} [mm]
8/200/65	7.89	5.75	200.1	65.22	6.94	4.76
10/300/80	9.89	6.92	299.9	69.82	8.85	6.80
12/200/80	11.76	8.76	200.4	79.96	10.68	7.88
12/400/100	11.82	8.66	400.5	99.72	10.64	7.87

6.2 Characteristic yield moment

Testing equipment, position of specimen and position of LVDT at yield moment test are presented in Figure 4 and Figure 5.

Half of specimens in each group were tested on threaded section and half of them on non threaded section. Test results are presented in Table 3. Detailed results can be found in Annex A.

All tests were conducted as planed. No cracks were observed on specimens at angle α_k.

Table 3: Characteristic yield moment – test results

Group of specimens	Nominal dim. [mm]	Bending angle α [°]	$M_{y,average}$ [Nmm]	$M_{y,k}$ [Nmm]	α_k [°]	Presence of cracks at α_k (all specimens in group)
L11094/A8_200/1 - 10	8/200/65	10.5	33123	**27204**	21.1	no cracks observed
L11094/A10_300/1 - 10	10/300/80	9.0	59123	**42926**	19	no cracks observed
L11094/A12_400/1 - 10	12/400/100	7.9	97975	**81794**	17.9	no cracks observed

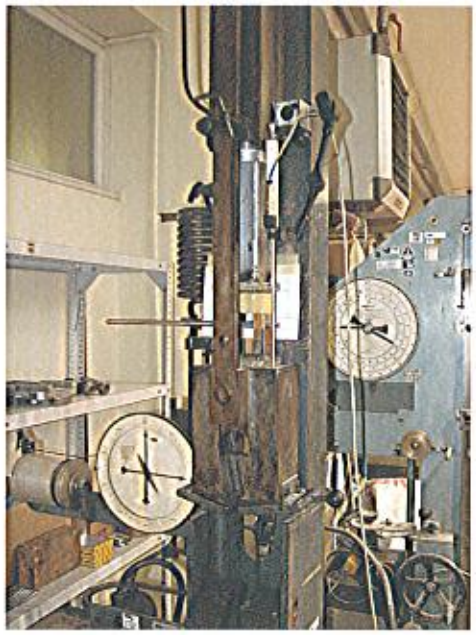

Figure 4: Yield moment test: Testing equipment

Figure 5: Yield moment test: Test on threaded part of screw

6.3 Characteristic withdrawal parameter

Testing equipment and position of specimen at withdrawal parameter test are presented in Figures 6, 7, and 8.

Test results are presented in Table 4. Only one piece of timber was used for each test group. Penetration depth l_p used for withdrawal parameter calculation was measured for each specimens separately.

Results for specimen L11094/C8/200/2 were not taken into consideration due to the fact that this screw was installed into a knot.

Detailed test results can be found in Annex A.

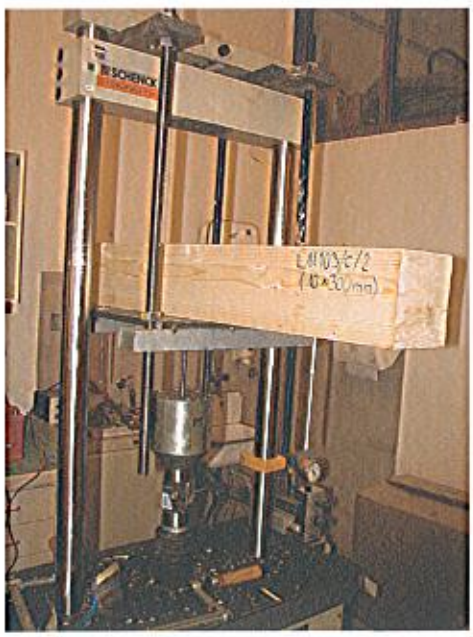

Figure 6: Withdrawal parameter test – testing equipment (1)

Figure 7: Withdrawal parameter test – testing equipment (2)

Figure 8: Withdrawal parameter test – testing equipment (3)

Table 4: Characteristic withdrawal parameters – test results

Group of specimens	Nominal dimensions [mm]	l_p [mm]	ρ^* [kg/m^3]	$F_{ax,average}$ [kN]	Average withdrawal parameter $f_{ax,average}$ [N/mm^2]	Characteristic withdrawal parameter $\mathbf{f_{ax,k}}$ [N/mm^2]
L11094/C8_200/1-10	8/200/65	64.87	458	8.79	16.94	**14.41**
L11094/C10_300/1-10	10/300/70	72.89	456	10.81	14.83	**12.73**
L11094/C12_200/1-10	12/200/80	78.78	447	14.76	15.61	**13.33**
L11094/C12_400/1-10	12/400/100	102.46	463	21.11	17.23	**11.56**

* Single timber piece was used (see Figures 7-9).

None of tested screws tear in tension – all screws were pulled out of timber.

6.4 Characteristic torsional ratio

Testing equipment for performing torsional resistance to insertion test is presented in Figure 9.

Figure 9: Torsional resistance to insertion of screws – testing equipment

Testing equipment and position of specimen at torsional strength test are presented in Figures 10 and 11.

Figure 10: Torsional strength test

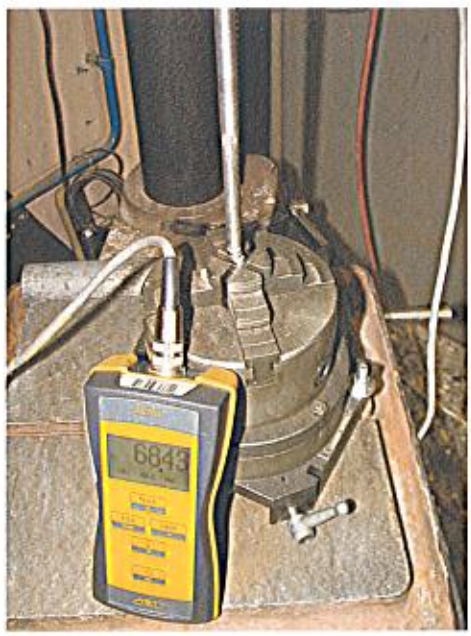

Figure 11: Torsional strength test - detail

The point of destruction at torsion strength test was most commonly in the area threaded timber section – untreated section. No unexpected failures occurred.

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

The results – characteristic torsional ratios – are presented in Tables 5. Values of average and characteristic resistances to insertion are already adjusted to average timber density 450 kg/m^3.

Table 5: Torsional ratio

	Torisonal strength (B)		Resistance to insertion (BR)			
Group of specimens [B / BR]	$f_{tor,\,average}$ [Nm]	$f_{tor,k}$ [Nm]	$R_{tor,\,average}$ [Nm]	$R_{tor,\,k}$ [Nm]	ρ [kg/m^3]	**ratio**
L11094/B(or BR)8_200/1-10	**38.78**	**37.95**	**6.40**	**5.17**	473	**7.34**
L11094/B(or BR)10_300/1-10	**69.56**	**68.03**	**12.10**	**9.67**	460	**7.03**
L11094/B(or BR)12_200/1-10	**123.3**	**120.63**	**22.75**	**18.01**	468	**6.70**
L11094/B(or BR)12_400/1-10	**122.4**	**115.87**	**26.17**	**22.75**	480	**5.09**

6.5 Characteristic tensile strength

Testing equipment, position of specimen at tensile strength tests are presented in Figures 12 and 13. Screws with diameter 12 mm were tested in Zwick 2500Z testing machine.

The point of destruction was most commonly in the threaded area section: screws with diameter 8 and 12 mm tear in the area of metric thread and screws with diameter 10 mm in the area of timber thread. Diameter related failures are also evident form the force displacement diagrams (see Annex B). Diagrams for screws with diameter 8 mm and 12 mm have evident plateu between yield point and fracture point while this is not the case for screws with diameter 10 mm.

Test results are presented in Table 6. Detailed test results are presented in Annex A.

Table 6: Average and characteristic tensile strength of screws

Group of specimens	Nominal dim. [mm]	$f_{t,average}$ [KN]	$f_{t,k}$ [kN]
L11094/A8_200/1-10	8/200/65	27.65	27.06
L11094/A10_300/1-10	10/300/80	42.47	41.72
L11094/A12_400/1-10	12/400/100	59.67	58.99

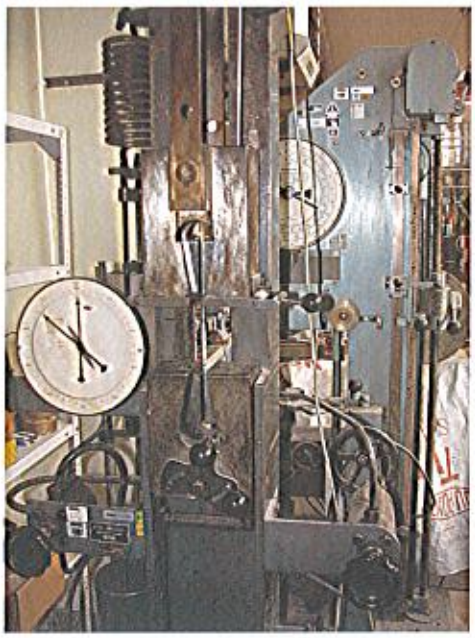

Figure 12: Tensile strength test (d = 8, 10 mm)

Figure 13: Tensile strength test (d = 12 mm)

7 Conclusions

The purpose of presented testing was to evaluate the performance of Tecfi NW51 timber screws with the requirements defined in EN 14592:2008. On the basis of the measurements of screws and on the basis of mechanical 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 screws comply with the requirements of EN 14592:2008.
- The values of characteristic yield moment $M_{y,k}$ are in range from 27204 Nmm (d = 8 mm) to 81794 Nmm (d = 12 mm). No cracks were observed at angle α_k.
- The values of characteristic withdrawal parameter $f_{ax,k}$ are in range from 11.56 N/mm^2 (d = 12 mm, l = 400 mm) to 14.41 N/mm^2 (d = 8 mm, l = 200 mm).
- The values of torsional ratio are in range form 5.09 (d = 12 mm, l = 400 mm) to 7.34 (d = 8 mm, l = 200 mm).
- The values of characteristic tensile strength $f_{t,k}$ are in range form 27.06 kN (d = 8 mm) to 58.99 kN (d = 12 mm).

An overview of test results is given in Table 7.

Table 7: Test results

d^* [mm]	$l_{nom}{}^*$ [mm]	$M_{y,k}$ [Nmm]	$f_{ax,k}{}^{**}$ [N/mm^2]	$f_{tor,k}$ / $R_{tor,k}{}^{***}$	$f_{t,k}$ [kN]
8	200	27204	14.41 (ρ = 458 kg/m^3)	7.34	27.06
10	300	42926	12.73 (ρ = 456 kg/m^3)	7.03	41.72
12	200	x	13.33 (ρ = 447 kg/m^3)	6.70	x
12	400	81794	11.56 (ρ = 463 kg/m^3)	5.09	58.99

* Diameter / length defined by manufacturer.

** Single piece of timber.

*** Adjusted to average timber density 450 kg/m^3.

Therefore it can be concluded that tested screws fulfil the geometry requirements defined in EN 14592:2008. All – for this type of screws – relevant mechanical characteristics evaluated from the test results are also above the standard requirements.

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