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Tests of load-bearing capacity for corner fittings of casement frames in wooden windows

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Abstract: *Tests of load-bearing capacity for corner fittings of casement frames in wooden windows.* The paper presents the results of tests for load-bearing capacity of corner fittings of wooden casement frames in single-frame windows. The objects tested were corner fittings with different joining structures and corner fittings made of sills with different cross-sections. The purpose of the research was to define assessment criteria and testing methods for wooden corner fittings with different sections of casement sills and different types of joints. The tests were conducted applying two independent testing methods. Analysis of the results obtained confirmed that the testing method from standard PN-88/B-10085/A+A3 [1], related to typical tenon-bridle joints (2 and 2.5 tenons), could be applied to other types of corner fitting structures for casements in which, apart from the gluing process, mechanical elements are introduced, such as bolts, studs, pads, etc

INTRODUCTION

Growing demand for wood, imposing at the same time more efficient management of the material, and complexity of window structures make window designers look for other types of joints for frame corner fittings in order to reduce material, time, and financial outlays in window and door joinery. Finding optimal solutions requires taking into account many factors indeed, e.g. related to strength, technology, ergonomics, economy or aesthetics. A special place in the structure of a window, from the point of view of strength, is joints in the corner fittings of frames, mainly casement frames. These are required to have adequate strength and durability and thus to assure a given window's structural safety and long life.

Various structural solutions are applied to joints in corner fittings of casement frames in modern windows. The only document specifying the characteristic load-bearing capacity of sill joints in corner fittings for casements of wooden windows and balcony doors was Polish standard PN-88/B-10085/A2 [1], which has been repealed. However, it did not take into account different cross-sections of casement frame sections and did not differentiate various structural solutions to the very joints of frame sills. Neither did it determine the requirements for corner fittings of roof windows. In 2007, it was replaced by standard PN-EN 14351-1+A1:2010 Windows and doors. Product standards [3], the scope of which does not cover problems of this kind.

From the point of view of a window's functionality, usability, resistance to the loads affecting it, such as wind pressure and suction, as well as operational loads, the strength of a frame corner fitting in a casement of a wooden window plays a very important role and cannot be omitted during an assessment.

The structural type of a joint for a casement corner fitting also includes the following aspects:

- location of building in (vertical windows, roof windows),
- way of opening window casements,
- way of glazing the window casements,
- presence of elements that brace frame profiles, e.g. covering aluminium sections mounted to the outer surface of casement sills in wooden-aluminium windows.

Until recently, the leading system among single-frame wooden windows was DJ68, in which the cross-section of casement and frame elements was 68x78mm. The structure of a corner fitting for a casement frame was based on a typical glued tenon-bridle joint with 2 and 2.5

tenons. New structural solutions joined the one described above in the last few years, such as roof windows and wooden-aluminium windows, in which sill cross-sections (especially in roof windows) are often smaller, e.g. of 62x44 mm, 60x66 mm, 56x66 mm, and the structure of joining corner fittings with casement frames does not always suit a typical tenon-bridle joint. Additionally, in order to assure the strength and rigidity of a corner fitting, gluing is enhanced by mechanical elements such as bolts, studs, pads, etc. Besides, the casement sill's cross-section and the gluing surface are reduced at the same time.
The mechanical elements introduced to a corner fitting can fulfil various functions, such as:

- strengthening, i.e. stiffening a joint through improving its strength parameters,
- making the installation of joints easier and faster in order to reduce or eliminate the gluing process,
- protecting – this mainly concerns joints that are exposed to long-term impacts of time and variable weather conditions,
- decorative function.

Today's single-frame wooden joinery includes three principal groups of joints for frame corner fittings, namely:

- glued tenon-bridle joints and glued tenon-bridle joints with metal pads type "corrugated clamps" or "corrugated nails",
- glued joints reinforced with wooden studs ,
- glued joints with mechanical elements, i.e. various types of nails and bolts.

The CSTB institute in France has developed a test method that may be applied to any type of an angle wood joint, regardless of its method of joining. It concerns joints (corner fittings of frames) in which joining through gluing, through gluing reinforced with a pad or pads, or through mechanical elements only, i.e. bolts with no glue, was applied.

This method covers joints for frame corner fittings, regardless of their location in a window, i.e. the casement and frame, and takes into consideration the work of a window due to loads operating in its plane. However, it is mainly addressed to casements that open along one of their vertical edges. For each batch, compressed and stretched samples are analysed separately here, therefore the tested samples should be clearly defined, i.e. as taken out of top and bottom sills.
Table 1 shows technical requirements for different structures of joints in corner fittings.

Table 1 Strength requirements for frame corner fittings according to the French technical conditions [2]

Parameters	Residual deformation D_{rk}	Angular deformation (T_k)	Minimum breaking moment (T_{kmin})	Minimum breaking force F_{max}
Units	%	N·m	N·m	N
*Traditionally glued joint	**≤25**	**≥80**	**≥100**	**≥330**
**Glued joint containing pad(s)	**≤35**	**≥40**	**≥100**	**≥330**
***Mechanical joint	**≤35**	**≥15**	**≥90**	**≥300**

*Traditional glued joint – a joint whose strength is provided by the presence of "integral pads", i.e. a tenon, tenons or fixing pads, which are glued into "counter-pads", i.e. a mortice, mortices, a bridle, bridles or into openings;

**Glued joint containing pad(s) – a joint whose strength is provided by:

- bolts (screws) fixed directly into wood or in pads located in adequate, pre-determined places of a joint or; a joint is not glued on the surface of a sill, but a glue or filler covers the outer surface of the joint to make it tight;
- by one or more pads;

*** Mechanical joint – a joint whose strength is assured by bolts (screws) fixed directly on the edge of wood or in pads located in adequate, pre-determined places of a joint; the joint is additionally glued along the whole surface of a sill.

This paper shows results of the tests performed on corner fittings for casement frames of single-frame wooden windows with different structures and joining methods in order to determine adequate assessment criteria and test method. The tests were performed using two methods in order to verify their usefulness for different structural solutions.

EXPERIMENT

Method 1 – used in Poland according to PN-88/B-10085/A2+A3 [1] and Method 2, the so-called "French method", based on a French procedure developed at CSTB [2].

The scope of testing of the two methods covered:

- visual assessment of a joint in a corner fitting and its correctness,
- determination of the minimum breaking force,
- description of damage type,
- measurement of humidity

The tests were performed on samples taken directly from production lines. The samples were collected from casements of single-frame windows, made of pinewood and with different structures of the joint. 5 different structural solutions were tested, namely:

- joint based on 2.5 tenons + glue + 2 nails (corner fitting of a roof window) – type A structure,
- joint based on 3 tenons + glue + nail (corner fitting of a roof window) – type B structure,
- joint based on 2 tenons + glue + metal clip (corner fitting of a Scandinavian window) – type C structure,
- joint based on 2.5 tenons + glue + steel pad (corner fitting of a vertical window) – type D structure,
- angle-profile joint butted with glue; two ϕ12mm studs inserted into sills + ϕ7mm wood screw in vertical sill (corner fitting of a vertical window) – type E structure.

The samples were collected from top and bottom sills of a casement. The technological cuts, seats for fittings or clean locks envisaged by the technical documentation were made in the samples to be tested. 10 samples of corner fittings were tested for each batch.

The tests acc. to Method 1 were performed in a sampling machine designed to expose samples to bending through compressing, until destroying them. The force was measured with the accuracy of ± 10N. A sample was exposed to the load with the head advance rate of 20mm/min. The samples to be tested were prepared as show in Fig. 1.

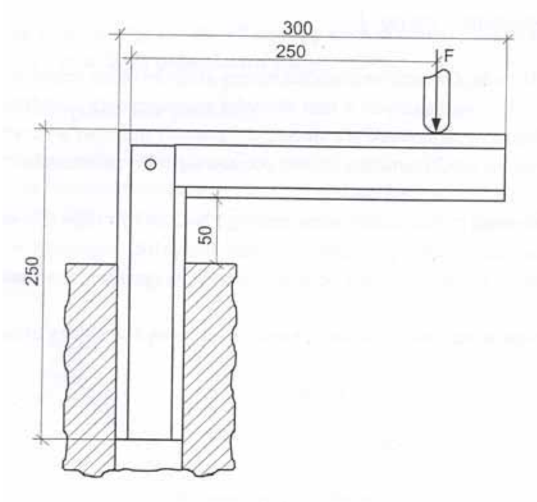


Fig. 1. Shape, dimensions and load affecting a corner fitting of a casement, method 1

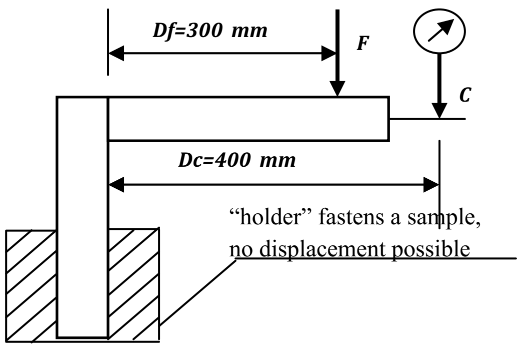
The result of a single test was the load-bearing capacity expressed in newtons (*F_{vi}) [N]*, while the final result for a batch tested (10 pieces) was the characteristic load-bearing capacity (*F_{vk}).*

After the testing, humidity was measured acc. to PN-84/D-04150 [4], using the electrometric method, at one point of the wider surface of each section of wood joins.

The humidity of all tested samples fell within the range of 10%÷16%. No cracks or mechanical dam-

age of the joints were found during the visual assessment of their quality in all the tested samples.
Detailed results of the tests are given in Table 2.
It should be added that the test method applied, i.e. Method 1 acc. to [1], relates to the typical "tenon-bridle" joint for corner fittings of casement frames, which is found in window system DJ-68. The method does not address other structural solutions.

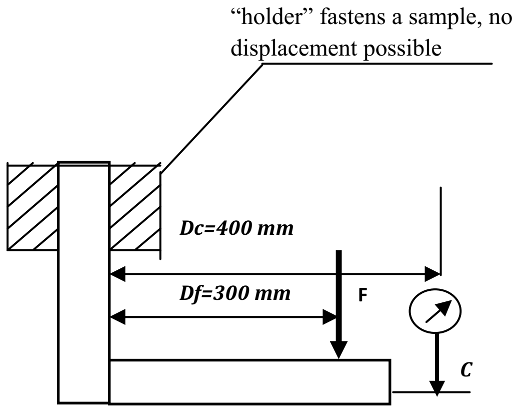
The tests according to **Method 2** were conducted for 5 different solutions (enumerated above), for 20pcs. from one batch. The samples were exposed to two moments: 10pcs.were affected by compressing (**Fig. 2**) and 10pcs by stretching (**Fig. 3**).



F[N] - force applied to compress a corner fitting

Df[mm] – distance from the force application point to the turn-over point of the vertical sill

Fig.2. Shape, dimensions and compressing load affecting a wooden corner fitting



F[N] - force applied to stretch a corner fitting

Df[mm] – distance from the force application point to the turn-over point of the vertical sill

Fig. 3. Shape, dimensions and stretching load affecting a wooden corner fitting

The samples of one batch (20pcs.) came from one production batch that was representative for the assessed structural solution. Before the tests, the samples had been prepared under laboratory conditions for 7 days, in a chamber with normal climate, i.e. at a temperature of 20 ± 2^0C and a relative humidity of 65±5%.
After the conditioning had concluded but prior to fastening the samples inside the testing machine, the joint were inspected. No cracks or mechanical damage of the joints were found in all the tested samples.

Individual samples were fastened by a "holder" of the testing machine, which gave them no possibility of being displaced. Next, the loading head was set at a distance of 300mm from the main plane of the joint's turn-over point and placed at mid-width of the lengthwise element of the tested corner fitting. The linear velocity of the loaded sample was 30mm/min. The moment was applied to the sample in two steps, i.e. until achieving the defined deformation and, after a time of rest, till breaking the sample. The result of the test was:

- moment ($T_{\omega i}$) (for the i-th sample) at an angular deformation of $1^{o,}$

$$T_{\omega i} = F_{\omega i} \cdot D_f \tag{4}$$

$F_{\varpi i}$ - operating force [N]

D_f -arm where the applied force operates [m]

$T_{\varpi i}$ - moment expressed in [Nm]

– residual deformation (for the i-th sample) (D_{ri}),

$$D_{ri} = 100 \cdot \frac{d_{ri}}{d_{1i}} \tag{5}$$

D_{ri} - residual deformation (for the i-th sample) [%]

d_{ri} -residual deformation [mm]

d_{1i} -sensor dislocation at an angular deformation of 1° (for the i-th sample)

- moment upon breaking the sample (breaking moment) (T_{ri}).

$$T_{ri} = F_{ri} \cdot D_f \tag{6}$$

F_{ri} -breaking force [N] (for the i-th sample)

D_f -arm where the applied force operates [m]

T_{ri} -breaking moment [Nm] (for the i-th sample)

- minimum breaking force for the sample (F_{min}).

$$T_{ri} = F_{ri} \cdot D_f \tag{7}$$

F_{ri} -breaking force [N] (for the i-th sample)

D_f -arm where the applied force operates [m]

T_{ri} -breaking moment [Nm] (for the i-th sample)

The obtained values were statistically analysed and the characteristic values obtained (D_{rk} - residual deformation, T_k - angular deformation T_{kmin} – minimum breaking moment, F_{min} – minimum breaking force) were compared with the adequate boundary values of reference stated in the Table 1.

After the testing, humidity was measured acc. to PN-84/D-04150 [4], using the electrometric method, at one point of the wider surface of each section of wood joins. The humidity of all tested samples fell within the range of 10%÷16%.

Table 2 shows sample results of the testing (after the statistical analysis), as compared with the requirements of the standard [1] and the French technical requirements [2].

Table 2 Characteristic load-bearing capacity Fvk [N] of sill joints in casement corner fittings

BATCH	**Structural type**	**Characteristic load-bearing capacity of sill joints in case-ment corner fittings F_{vk} [N]** – obtained during tests acc. to PN-88/B-10085/A2+A3 **[1]**	**Characteristic load-bearing capacities of sill joints in casement corner fittings [N] –** obtained during tests acc. to the "French method" **[2]**			
Force direction		**compressing**	**compressing**		**stretching**	
			Force at an angular aperture of 1⁰- $F_{\alpha k}$[N]	**Breaking force F_{rk} [N]**	**Force at an angular aperture of 1⁰- $F_{\alpha k}$[N]**	**Breaking force F_{rk} [N]**
1	A	**742**	479	**365**	689	**840**
2		**387**	584	**596**	---**	---**
3	B	**379**	311	**360**	366	**481**
4		**533**	457	**481**	385	**579**
5*	C	**85**	286	**421**	228	**243**
6	D	**1,750**	1,698	**1,728**	1,724	**1,760**

7		**488**	511	**514**	524	**587**
8		**1,465**	1,437	**1,456**	1,469	**1,476**
9	E	**970**	742	**821**	984	**1,012**

* a very limited quantity of glue brought to the surfaces of tenons was reported for this type of joint.
** the test was not performed

Table 3 Strength of sill joints in casement corner fittings compared with the French requirements [2]

Batch	**Structural type**	**Residual deformation D_{rk}**		**Moment at angular deformation - T_{ω}**		**Maximum breaking moment T_{kmax}**	
Force direction		**compressing**	**stretching**	**compressing**	**stretching**	**compressing**	**stretching**
1	A	6	7	144	255	109	252
2		6	---	175	---	179	---
3	B	7	3	93	109	109	144
4		5	6	134	116	145	174
Requirement (joint glued with pads)		**≤35**		**≥40**		**≥100**	
5	C, D	0	2	69	86	76	126
6		1	1	509	517	519	529
7		1	1	153	157	155	176
8		2	0	431	441	437	443
Requirement (joint glued with pads)		**≤35**		**≥40**		**≥100**	

Note: the requirements [2] do not address the E-type structure

Analysis of the test results

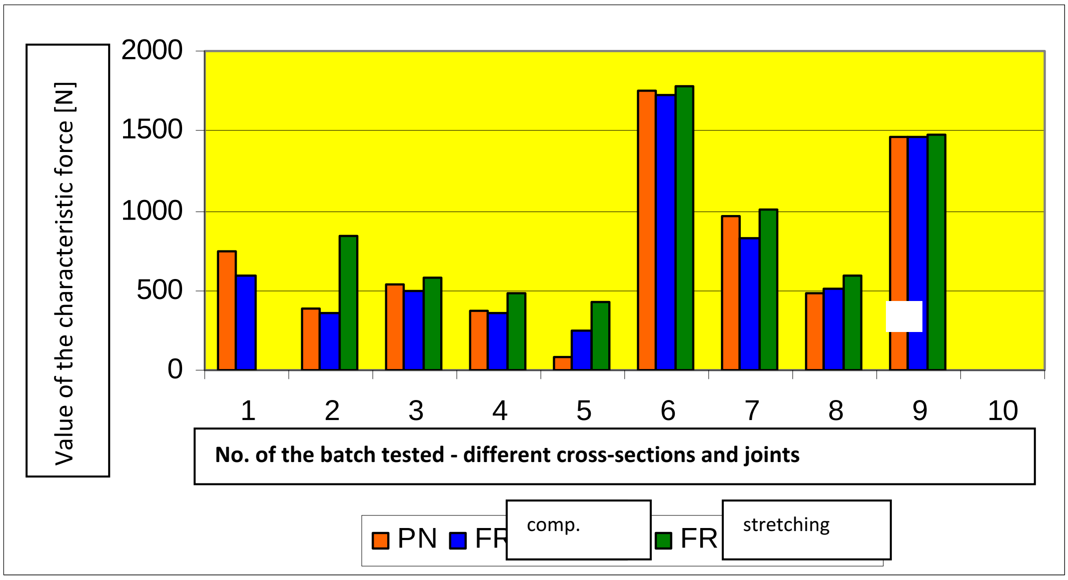
Tables 2 and 3 compare the minimum characteristic load-bearing capacity F_{vk} , as a statistical assessment of the test results, including an estimation of the lower limit of confidence interval using Student's t-distribution. The assessment covered the test results obtained as a result of applying the two methods, i.e. the one acc. to PN-88/B-10085/A2+A3 [1] and the French procedure [2]).

The fixed factors during the tests were:

- sample model adopted for the testing
- load application rate defined for the samples
- load application system determined for the samples (depending on the adopted test method).

The essential difference between the Polish method acc. to PN-88/B-10085/A2+A3 [1] and the French one [2] is the system of applying load to samples. According to the Polish method [1], the samples are exposed to compression through bending, while according to the French one [2], they are exposed to loads in both directions, i.e. for compression through bending and for stretching through bending. Additionally, the French method requires to record the displacement of the loaded casement sill while applying the preliminary and breaking loads. Frequently, the preliminary load is at the same time the breaking load. In the case of well-adjusted joining elements of a corner fitting and when glue is carefully distributed, the displacement of a casement sill is limited and when preliminary load 1^0 is applied, the sill is destroyed. Therefore, the boundary values of angular deformation stated in the French technical requirements [2] are far higher than the testing results obtained. Maybe the requirements regarding the angular deformation are justifiable, but rather for corner fittings of dry-joined casements, with no adhesive-bonded joint applied, where it would be possible to achieve the casement sill displacements proposed by the French. Comparing the results obtained from

testing the minimum breaking force according to the French method [2], it is found that lower values of the strength of a corner fitting were recorded for samples that were exposed to compressing through bending. The minimum breaking force for the same type of corner fitting, but with the load application system oriented to bending through stretching, exceeded the force applied while bending through compressing. Exposing a sample to loading for compressing is decisively more adverse than for stretching. Relating this to the structure of a casement frame alone, its upper parts are more exposed to deformation than the lower ones, due to the forces that operate while using on the casement's plane.
Graph 1 presents examples of relations between the results of the tests for the minimum breaking force conducted according to the two test methods, [1] and [2].



Graph 1. Values of the characteristic force for different types of joints, obtained during the tests according to the method of PN-88/B-10085/A2+A3 [1] and the French method [2], for bending through compressing and bending through stretching.

The analysis showed that the highest value of the characteristic breaking force was recorded for the corner fittings exposed to bending through stretching. The characteristic values of the minimum breaking force for compressing through bending are lower both in the case of the Polish [1] and the French method [2].

CONCLUSIONS

On the basis of the laboratory tests performed, it is concluded that:

- The compressing load upon corner fittings in casement frames of single-frame wooden windows is definitely more adverse than the stretching load.
- The mechanical joints used in the tested structural solutions, such as bolts, pads, corrugated clips or nails, applied along with the basic joining elements of a corner fitting, i.e. tenons and bridles, did not increase the strength of the corner fittings though stabilised them during the process of gluing.
- Regardless of the structure of a corner fitting and the cross-section of sills, the method described in standard PN-88/B-10085/A2+A3 [1] is useful when the structure of a corner fitting departs from a typical tenon-bridle joint system for 2 and 2.5 tenons.

REFERENCES

1. PN-88/B-10085/A2+A3 "Building joinery. Windows and doors. Requirements and tests"
2. "French test method" "Translated text of a preliminary draft of the French procedure concerning the assessment of joints with various methods of combining
3. PN-EN 14351-1+A1:2010 "Windows and doors. Product standards, performance Characteristics. Part 1 – Windows and external pedestrian doors without resistance to fire and/or smoke leakage"
4. PN-84/D-04150 "Sawn timber. Determination of humidity"

Streszczenie: *Badania nośności naroży ram skrzydeł w oknach drewnianych.* W pracy zaprezentowano wyniki badań nośności naroży ram skrzydeł drewnianych okien jednoramowych. Przedmiotem badań były naroża o różnej konstrukcji łączenia oraz naroża wykonane z ramiaków o różnych przekrojach poprzecznych. Celem pracy badawczej było opracowanie kryteriów oceny i metod badań naroży drewnianych przy różnych przekrojach ramiaków skrzydeł i różnych rodzajach połączeń. Badania przeprowadzono dwoma niezależnymi metodami badawczymi. Analiza otrzymanych wyników badań potwierdziła, iż metoda badania przewidziana normą PN-88/B-10085/A2+A3 dotycząca połączeń typowych czopowo-widlicowych (2 i 2,5 czopa) może być stosowana do innego typu konstrukcji naroża skrzydła okiennego gdzie obok klejenia, wprowadza się elementy mechaniczne takie jak śruby, kołki, wkładki itp..

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