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The Strength Determination of Corner joints used for Wooden Windows

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Abstract: *The Strength Determination of Corner joints used for Wooden Windows*. The work is aimed at the methodical procedure assessment of rectangular corner joints applied on window casement and its strength. Mechanical properties of testing samples are further evaluated by universal testing machine. For this reason a component necessary for fixing corner joints has been designed. The testing samples are loaded by bending moment with tensile and compressive forces. The values obtained in testing are further used in final equations for calculating the values of joint stiffness and bending moment capacity of which will help to decide which joint is preferable for construction applications.

Keywords: corner joint, strength, stiffness, bending moment, deformation

INTRODUCTION

The selection of optimal typology of joint has to be chosen and designed to provide its functionality such as wooden window frames, which are loaded by forces as well as by climatic conditions. The profile of members is reduced in the area of connections and it makes the members weaker. For this reason reliable and durable joints are required in every single construction. Many types of joints of different stiffness are used by window manufactures today. However, no methodology has been proposed to measure the strength of rectangular corner joints made of wood. It is only one method that is proposed in ČSN EN 514. This standard is focused on joints (corner and „T"-joints) made of PVC-U profiles in windows and doors applications. Many methodologies have been investigated in the articles dealing with furniture corner joints designing (JOŠČÁK 1999; JOŠČÁK – KOLLÁR 2007; DERIKVAND *et al.* 2014). Figure 1 shows the most frequent methods for corner joints testing. The testing samples are loaded by tensile and compression loadings in the angular plane.

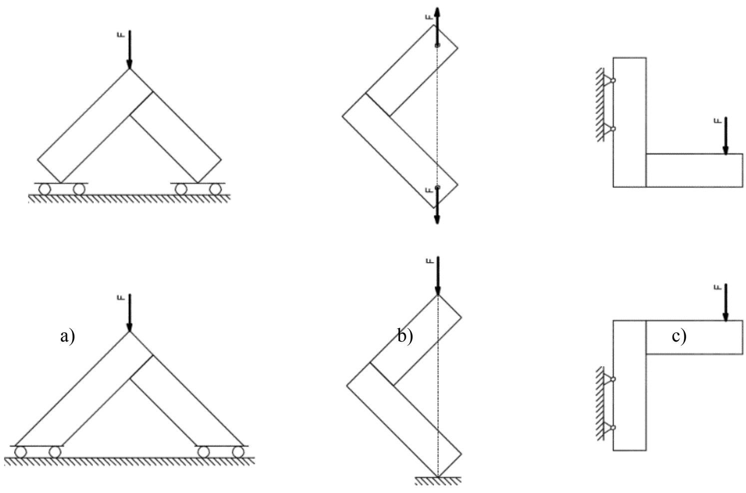

Figure 1. Testing methods: in tensile - a) by JOŠČÁK 1999, b) by JOŠČÁK – KOLLÁR 2007, c) and d) by ČSN EN 514; in compression – e) by JOŠČÁK 1999, f) by PANTALEO et. al 2014

MATERIALS

This methodology was applied to the rectangular (γ_0 = 90°) corner joints used on a wooden casement. A series of identical (material, corner joints, types of glue, sizes and dimensions of profiles) testing samples were tested. The samples were provided by the window manufacturers. The surfaces of the testing samples were milled and smoothed without any surface treatment. The glass (including glazing beads), window hardware (hinges, screws and locks) and seals were not fixed. The testing samples were conditioned so that the equilibrium moisture content (around 12 %) in the ambient conditions with air temperature 20 °C (± 2 °C) and the relative humidity of air 65 % (± 5 %) could be reached.

For this method, a new fixing component was designed (Figure 2). This component is universal and can be used for both methodical testing, for different types of joint with different sizes of profile. If the samples are to be properly fixed in the fixing component, it is necessary to drill a hole through the sample. The holes had to be placed at least 30 mm from the outer edge of testing samples. They were drilled by a pillar drilling machine with a drill 11 mm (± 0, 5 mm) in diameter, as the pin diameter designed in a fixing component was 10 mm. These holes were always drilled in the same distance *a* and *x* (precision being ± 1 mm).

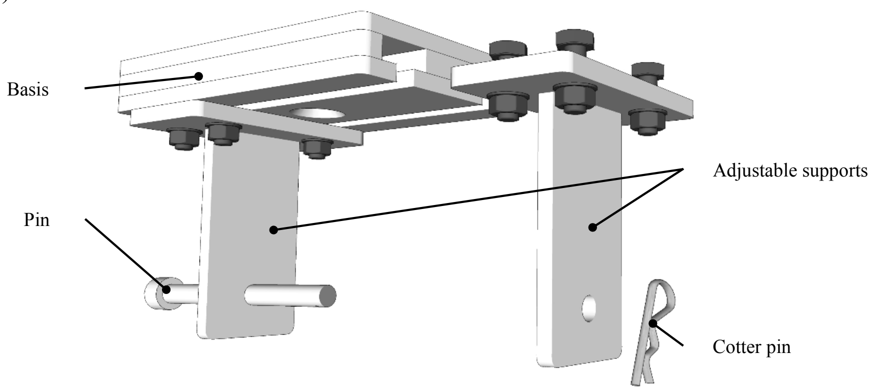

Figure 2. Model of designed fixing component (Author)

The minimum number of testing samples *n* in one series was established by the formula (1) and accuracy d_α cannot be less than 5 % (DUBOVSKÝ *et al.* 2001):

$$\boldsymbol{n} = \frac{\boldsymbol{t_\alpha^2} \times \boldsymbol{v^2}}{\boldsymbol{d_\alpha^2}} \qquad (1) \qquad [1]$$

where : t_α – Student's *t* distribution with level of significance $\alpha = 0{,}05$ or establishing 95 % confidence $(1 - \alpha)$ for $n - 1$,
v – coefficient of variation,
d_α – accuracy.

The methodology was based on the measurement of the bending moment capacity in compression testing M_c (10), and the bending moment capacity in tensile testing M_t (11). For this purpose tests were executed using a universal testing machine UTS 50 placed in the laboratory of the Department of Wood Processing, the Faculty of Forestry and Wood Sciences. The testing machine was supported by software TIRA. The range of admissible loading was from 0 to 50 kN. The fixing component mentioned was installed to the testing machine with the samples. The constant loading speed of the machine head was set up to 5 mm/min. The testing samples of corner joints were tested by the force up to the moment of joint breaking F_{max} and in the moment of break the linear displacement Δu was evaluated. The deformations in the place of the testing sample pin fixation did not occur and that was the reason for neglecting them. The testing set-up shows the Figure 3.

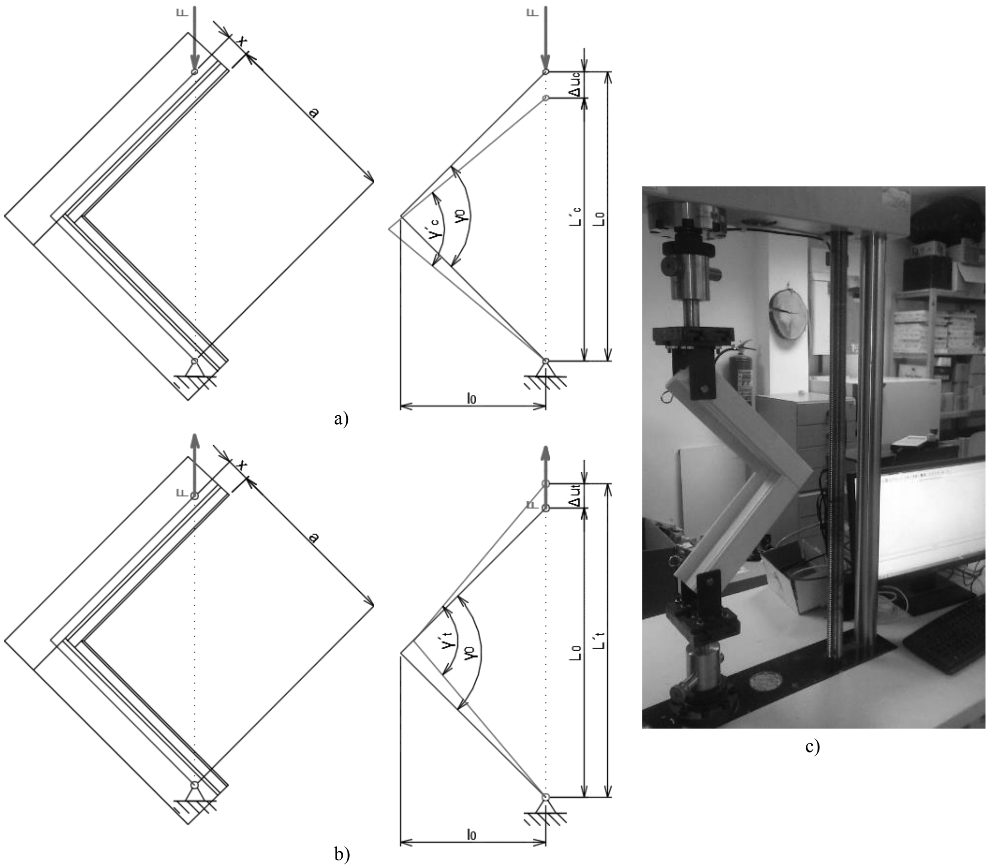

Figure 3. a) Compression testing, b) tensile testing, c) testing set-up (Author)

The geometry of fixed corner joints (Figure 3 a) and b)) was used for the creation of equations (2 – 9):

A. distance between the applied points of the forces at the beginning of the test L_0:

$$sin\frac{\gamma_0}{2} = \frac{\frac{L_0}{2}}{a+x} \rightarrow \boldsymbol{L_0 = 2\,(a+x) sin\frac{\gamma_0}{2}} \qquad (mm) \qquad [2]$$

B. distance between the applied points of the forces at the moment of joint breaking F_{max} in compression testing L'_c, or distance in tensile testing L'_t:

$$\boldsymbol{L'_c = L_0 - \Delta u_c} \qquad (mm) \qquad [3]$$

$$\boldsymbol{L'_t = L_0 + \Delta u_t} \qquad (mm) \qquad [4]$$

C. changed angle between the applied points of the forces at the moment of joint breaking F_{max} in compression testing γ'_c, or changed angle in tensile testing γ'_t:

$$\sin\frac{\gamma'_c}{2} = \frac{\frac{L'_c}{2}}{a+x} \rightarrow \boldsymbol{\gamma'_c = 2\,arcsin\left(\frac{L'_c}{2\,(a+x)}\right)} \qquad (°) \qquad [5]$$

$$\sin\frac{\gamma'_t}{2} = \frac{\frac{L'_t}{2}}{a+x} \rightarrow \boldsymbol{\gamma'_t = 2\,arcsin\left(\frac{L'_t}{2\,(a+x)}\right)} \qquad (°) \qquad [6]$$

D. angular deformation of corner joints arms in compression testing $\Delta\gamma_c$, or angular deformation in tensile testing $\Delta\gamma_t$:

$$\boldsymbol{\Delta\gamma_c = \gamma_0 - \gamma'_c} \qquad (°) \qquad [7]$$

$$\boldsymbol{\Delta\gamma_t = \gamma'_t - \gamma_0} \qquad (°) \qquad [8]$$

E. moment arm l_0 :

$$\cos\frac{\gamma_0}{2} = \frac{l_0}{a+x} \rightarrow \boldsymbol{l_0 = (a+x)\,\cos\frac{\gamma_0}{2}} \qquad (mm) \qquad [9]$$

The bending moment capacity M_c (10), or M_t (11) are directly proportional to the measured force at the moment of joint breaking F_{max} and moment arm l_0 (9). The moment M_c (10), or M_t (11) can be replaced by the moment increment in the elastic region for 10 % and 40 % of the mean value of the bending strength (WILCZYNSKI – WARMBIER 2000). If the bending moment capacity M_c (10), or M_t (12) are divided with the angular deformation of corner joints arms in compression testing $\Delta\gamma_c$ (7), or angular deformation in tensile testing $\Delta\gamma_t$ (8), we will get the stiffness coefficient of adequate corner joints c_c (12), or c_t (13), (JOŠČÁK 1999: JIVKOV *et al.* 2008):

$$\boldsymbol{M_c = F_{c,max} \times l_0} \qquad (N \times m) \qquad [10]$$

$$\boldsymbol{M_t = F_{t,max} \times l_0} \qquad (N \times m) \qquad [11]$$

$$\boldsymbol{c_c = \frac{M_c}{\Delta\gamma_c}} \qquad \left(\frac{\boldsymbol{N \times m}}{rad}\right) \qquad [12]$$

$$\boldsymbol{c_t = \frac{M_t}{\Delta\gamma_t}} \qquad \left(\frac{\boldsymbol{N \times m}}{rad}\right) \qquad [13]$$

CONCLUSION

This paper is concentrated on the universal strength tests of corner joints applied on window casement and the methodical procedure how of measuring the value of stiffness and bending moment capacity. Thanks to the designed fixing component, methodology is valid for both compression and tensile testing. The presented equations can be also used in furniture design as well. It is recommended to measure the value of stiffness and bending moment capacity especially in a wooden windows casement where the corner joints are mainly loaded with insulated double glazing glass or heavier triple glazing glass.

The values investigated were the influences of the breaking strength leading to differences in the inner angle and linear displacement. The paper does not mention the climatic conditions during the testing. Self-locking strength of joint have not been included either.

The calculations and the method will be further used in testing different types of corner joints of different profile sizes. This will lead to the selection of optimal types and sizes of joint, which will facilitate the selection of optimal joint for any construction.

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Streszczenie: *Wytrzymałość połączeń narożnikowych do okien drewnianych.* Praca dotyczy oceny procedur oceny połączeń narożnikowych w oknach drewnianych. Własności mechaniczne próbek oceniono na maszynie wytrzymałościowej. Zaprojektowano mocowanie połączeń w maszynie wytrzymałościowej. Próbki obciążano momentem zginającym przy ściskaniu albo rozciąganiu. Wyniki badań uwzględniono przy obliczeniach I ocenie przydatności konkretnych rozwiązań połączeń w zastosowaniach konstrukcyjnych.

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