Materials and Design 60 (2014) 260–266

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Technical Report

Elasticity modulus of cabinet furniture joints

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ARTICLE INFO

Article history:
Received 10 February 2014
Accepted 28 March 2014
Available online 8 April 2014

ABSTRACT

Designing of furniture stiffness with the assistance of computer aided engineering (CAE) requires determination of joint stiffness coefficients or realistic modelling of elastic bodies which remain in contact with one another. The objective of this study was to determine elasticity moduli of furniture L-type joints, numerical calculation of furniture stiffness with joints which were assigned elasticity moduli as well as verification of the results of these calculations employing, for this purpose, experimental investigations. The correctness of the elaborated model of joint elasticity modulus was verified positively by empirical studies. The developed model makes it possible to conduct an objective comparison of joint stiffness and, on this basis, to select the most advantageous solutions. The application of joint elasticity moduli simplifies numerical analysis of cabinet furniture construction.

1. Introduction

Furniture strength assessment should be initiated at the stage of their design process. Conformity certification of a given piece of furniture prototype always entails the need to bear considerably higher costs of eliminating the identified defects and mistakes [1–3]. One of the major quality evaluation criteria of cabinet furniture is their stiffness [4–9]. This stiffness depends, primarily, on the stiffness of the applied joints [4–25]. Studies on analytical models of cabinet furniture stiffness have been conducted since 1957 [4–8,26]. The results of those experiments revealed that for physical models connected with the assistance of various couplings, furniture deflections were lower in comparison with the calculated values. The main reason of the discrepancies was disregarding the influence of furniture joint stiffness on the rigidity of the entire construction. Therefore, many researchers focused their attention on the issue of stiffness and strength of furniture joints and their impact on the rigidity of the entire construction [10,11,21–24,26–38]. The main assessment criterion of joint strength was the value of the breaking force or bending moment. On the other hand, stiffness was evaluated on the basis of the deflection value along the direction of load application or on the basis of the value change of the angle between the arms of the joint. These results, albeit very important from the cognitive point of view, fail to make easier work for designing offices of furniture factories which employ the CAE (computer aided engineering) tool for rapid prototyping. Numerical modelling requires determination of joint stiffness coefficients or realistic modelling of elastic bodies which remain in contact with one another [39–43]. This kind of modelling is very accurate but also labour-consuming and impractical from the point of view of application by designing offices. For this reason, an attempt was made to elaborate a method of simplified modelling of furniture joint stiffness for the needs of numerical calculations [44]. In the proposed method, joint stiffness was expressed by means of a modulus of elasticity in the form of a load and deflection function.

The main goal of this study was determination of elasticity moduli of furniture L-type joints, numerical calculation of furniture stiffness with joints which were assigned elasticity moduli as well as verification of the results of these calculations employing for this purpose experimental investigations.

2. Methods and materials

2.1. Kinds of L-type joints

For experiments, standard connectors were selected ensuring possibilities of self-assembly by the user (Fig. 1). These were beech dowels Ø 8 × 35 mm (D), "konfirmat" screws Ø 7 × 50 mm (C), eccentric couplings with threaded mandrels Ø 5 mm (E1) and eccentric couplings with expanding mandrels Ø 8 mm (E2). Fig. 1 also gives characteristics of the provided holes. Shapes and dimensions of joints are presented in Fig. 2 and described in Table 1. Three kinds of 500 mm long (L) and two kinds of 150 mm long (S) joints were employed. The LCD joint consisted of two "konfirmat" type screws and two dowels without the use of glue. The LE1D joint comprised two eccentric couplings with threaded mandrels and two dowels without the use of glue, while the LE2D joints was made

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http://dx.doi.org/10.1016/j.matdes.2014.03.066
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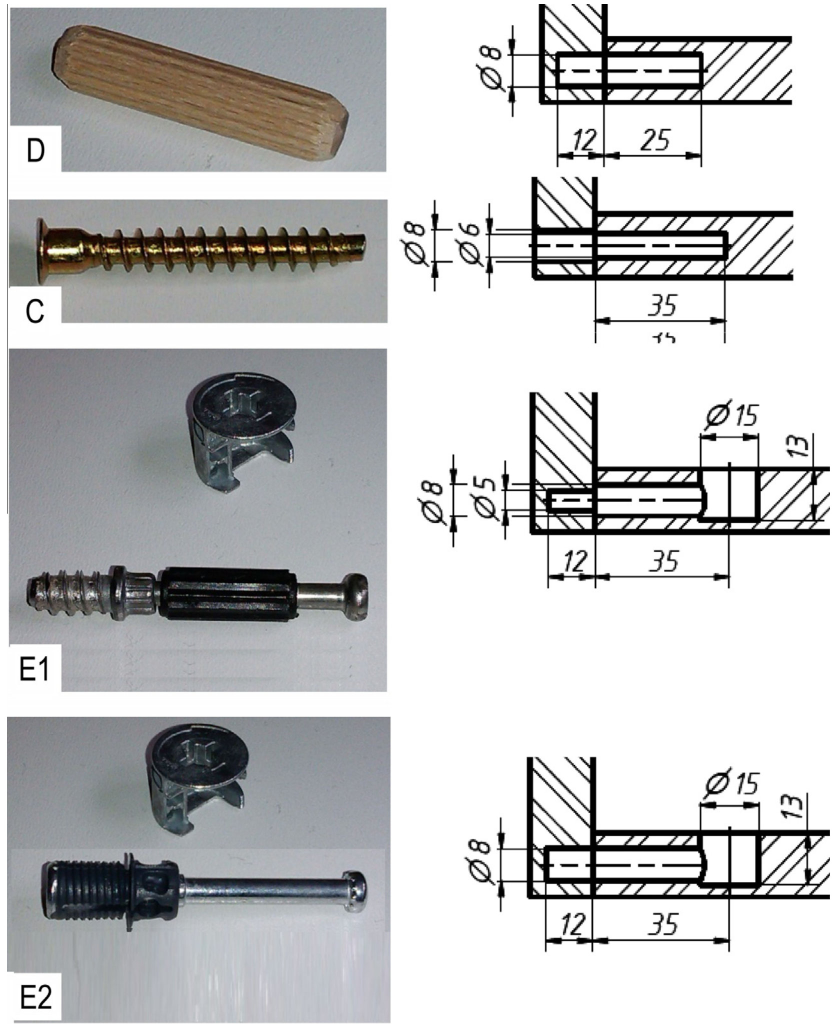

Fig. 1. Kinds of the applied joints: D – beech dowel; C – "konfirmat" screw; E1 – eccentric coupling with threaded mandrel; E2 – eccentric coupling with expanding mandrel.

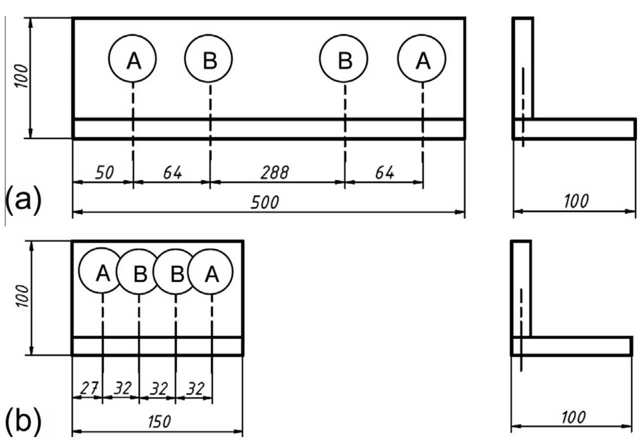

Fig. 2. Arrangement of connectors. Joint: (a) long *L*, (b) short *S*.

up of 2 eccentric couplings with expanding mandrels and two dowels without the use of glue. The SE1 joints contained two eccentric couplings with threaded mandrels without dowels, whereas the SE1D joints, additionally, contained two dowels without glue. Each joint was prepared in 10 replications, so the total number of samples was 50.

Joint arms were made of laminated chip board 16 mm thick. Prior to making experimental joints, the board was seasoned in the laboratory facility where the air relative humidity was kept at 65 ± 5% and the temperature at 21 ± 1 °C until the board reached constant mass. Additionally, it was decided to ascertain physic-mechanical properties of 2.5 mm thick HDF type boards lacquered on one side. The application of HDF boards was connected with the construction of the selected piece of furniture for which numerical calculations were carried out later on in the experiment. Board linear elasticity modulus and density were carried out in accordance with the appropriate standards [45,46] taking into consideration both the longer || and shorter ⊤ axis of the examined material (Table 2). The total of 90 samples, i.e. 15 samples for each treatment, was employed.

Table 1
Designations of the applied joints.

Designation	Length of joint (mm)	Type of joint (see Fig. 2)	
		A	B
LCD	L = 500	C = konfirmat	D = dowel
LE1D		E1 = eccentric coupling with threaded mandrel	
LE2D		E2 = eccentric coupling with expanding mandrel	
SE1	S = 150	E1 = eccentric coupling with threaded mandrel	–
SE1D			D = dowel