INTRODUCTION

Furniture is a product that combines art and technique, which affects the usefulness of the place with its functional value, makes the place look beautiful or ugly with its aesthetic value, makes the places we live or work in a warm and colourful environment [1]. Furniture and building elements are structures formed by combining more than one element in a construction with various shapes and methods, while gaining some features and functions. In this direction, when listing the factors that determine the quality or performance of a furniture or building element, it is necessary to count the quality of the material used in its construction, as well as its design in accordance with the purpose of use and various features and functions that it gains during the design and construction [2]. Wood species such as Elm, Walnut, Oak, which were frequently preferred in furniture production in the past, are now available in small quantities in the market. Due to this situation beech started to be more frequently requested and used by furniture manufacturers than before. Therefore, in this study, furniture joints made from beech wood have been studied, because it is easily available and has been frequently used in furniture production.

Domino wood dowels and Domino metallic connectors were used in the study. The Domino is a loose mortise and tenon joining tool manufactured by the German company Festool. In 2006, the company Festool introduced a reliable domino joiner system that creates strong hidden joints. This is a special type of joint using a loose tenon, or Domino pin, and mortises into which the Domino pin is inserted and glued [3]. This is a joining element with rounded edges, oval cross sections, and grooved surfaces. It is supplied in 14 different sizes. As a detachable interlocutor of the fixed wood Domino tenons, the so-called Domino metallic "connectors" were also developed. The domino wood dowels can be glued to the wood material by means of adhesives [3]. The metallic fasteners make flat or corner joints in wood components, providing simple, quick, and dismountable joints. The same tool is used to form the mortises in both mating work pieces, then depending on the joint type, a custom drilling template fits into the mortise to drill a hole that accepts the mating component of the connector. The metallic Domino connector joints are suitable to connect frames, panels, tops, sides, and other large joints, assure a robust connection strength and provide a rapid building, moving and reassembling of furniture components.

Wood material can be considered as a product today; it is used to achieve many purposes at functional, environmental and aesthetic levels. Most wood-based products are exposed to long lasting loads. This situation causes a continued mechanical deformation in the wood called

‘creep’ [4-7]. The main factors affecting the creep behaviour of wood material; : material itself (species of wood, growing characteristics etc.), time, temperature, load level and humidity [8-9]. Wood is classified as a viscoelastic material that will exhibit creep under prolonged loading [10].

OBJECTIVES

This study aimed to enhance the understanding of the behaviour of wood joints under static load, dynamic load and long-term load using different size Domino wood dowels and metallic Domino connectors. Special focus is on creep deformation. One of the main points in a design process for furniture production is to reduce the weight while keeping the strength of the wood parts at a sufficient level. Using different wood materials in furniture production can have technical, aesthetic, and economic advantages.

The main purpose of this study was to investigate the load bearing capacity of the corner and T-joints made of beech species and assembled using with Domino wood dowels and metallic Domino connectors. The research focused specifically on the following aspects:

- Determining the static, in-plane bending load bearing capacity of the Domino wood dowel and metallic Domino connector fastened corner and T-joints, by applying both compression and tension loading in the case of corner joints.
- Determining the dynamic, in-plane load bearing capacity of the Domino wood dowel and metallic Domino connector fastened corner and T-joints, by applying both compression and tension loading.
- Testing the pulling (withdrawal) resistance of T- joints connectors and the bending moment capacity of corner joints in the case of tension and pressure made with glued Domino dowels and removable Domino connecting elements.
- Studying and comparing the creep behavior of the Domino wood dowel and metallic Domino connector fastened corner and T-joints under sustained static load.

MATERIALS

For the test samples preparation European beech wood (Fagus sylvatica L.) was used with a mean density of 705 kg/m3 and 43 kg/m3 standard deviation. Beech wood species was selected due to its wide range of application in the European furniture industry. A part of the wood material contained red heartwood. From the conditioned boards slats and bars were prepared

with uniform width and thickness and in various lengths. From the slats and bars, corner joints (L-joints) for bending tests and T-joints for bending and withdrawal tests were prepared.

Joints of two different configurations were prepared. In the case of big-size specimens the 41.5 mm by 65 mm members were joined with their wider face perpendicular to the plane of frame, while the small-size were prepared of 22 mm by 40 mm members with their wider face in the plane of the frame. The orientation of the member cross-section defined the orientation of the connecting elements (Domino wood dowel and Domino metallic connector) as well with respect to the plane of the frame.

SAMPLE PREPARATION

For small size Domino wood dowels, the sizes of the fasteners were 40mm×22mm×8mm; the metallic Domino connectors were of size 42mm×22mm×8mm.

For big size Domino wood dowels, the sizes of the fasteners were 75mm×28mm×14mm; the metallic Domino connectors were of size 82mm×29mm×14mm with an additional 15 mm drill hole placed on the side to house the anchor nut. The fixing of the joint is made possible by a split anchor with threaded sides and a wedge inserted into one of the pieces and an anchor nut secured with a plastic tray in the other piece. The tight connection is achieved by turning the threaded shaft of the bolt, which stretches the anchor with the help of the wedge, and the wedge-grooved shaft of the bolt enables the stretching of the clamping screw. For the joint's preparations, the Festool's Domino Joiner DF 500 Q-Plus machine was used. By the way, the joints using Domino wood dowels were glued with a polyvinyl acetate (PVAc) type adhesive, specifically Ponal Super 3 from Henkel Ltd., with a solid content of 50+/-2% and D3 class of water resistance.

METHODS

- Static Tensile (withdrawal) Test: 40 test pieces each prepared from beech wood using Domino wood dowel and metallic Domino connectors were subjected to static tensile test in Instron Model 5566 Universal testing machine and static tensile values of the joints were obtained. This test was conducted based on the ASTM D 1761 standard.
- Static bending tests by diagonal compression and tension: To determine their strength performance 30 L-joints and 16 T-joints of beech wood, each prepared using Domino wood dowels and metallic Domino connectors, were subjected to static diagonal compression test, as well as 40 L-joints for diagonal tension test on Instron Model 5566

Universal testing machine. This test was conducted based on the ASTM D 1761 standard.

- Creep Test: for the creep measurement process, deflection gauges (comparators), some of them with digital display were used. Constant follow-up of the deflection of test specimens was performed during a period of 1 to 7 days, depending on the behaviour of the test sample under load.
- Cyclic Test: cyclic loading tests help to determine the fatigue life of a product during use. In this study, the cyclic loading was applied to each specimen setting up a test programme based on EN 12512:2001 in the Instron machine.
- Statistical analysis: STATISTICA statistical program package was used in the analysis of the data. In order to determine the effects of different parameters, such as specimen size and connector type, on the bending strength and stiffness values of the joints, a test of variance was conducted at the 5% significance level.

RESULTS AND THE THESES OF THE DISSERTATION

Thesis 1: Load carrying capacity of furniture joints made by using Domino wood dowels and Domino metallic connectors in static bending is governed by the size of connectors and member cross sections. Regardless of the position of their wider face when using the same wood species for the joint members. The ratio of small size specimens' load bearing capacity to that of big size ones is 57 to 82 per cent in case of the tested joint types.

Thesis 2: T-joints have higher resistance in static bending than corner joints do. Their load carrying capacity is more than double of that of corner joints in the case of metallic connector; the ratio is 1.22 for small size and 1.61 for big size joints with wood dowel connector.

Thesis 3: Deformation under unit moment of dismountable joints prepared with Domino metallic connector does not differ from that of their mates with wood dowel connector in the case of big size joints. In the case of small size joints, those with metallic connector are significantly more flexible.

Thesis 4: Rotation/moment coefficients expressed in 10^-4 rad /Nm indicating joint flexibility of semi-rigid joints in static bending were established for the types of joints under investigation. Both "working" values. i.e. measure of flexibility exhibited under service load (Z1) and final secant values based on deflection under ultimate load (Z) were established as below:

Joint type	Z1 (10^{-4} rad/Nm)	Z ($10^{\wedge-4}$ rad/Nm)
LBWD	0.51	3.4
LSWD	2.4	8.4
LBC	1.3	3.2
LSC	8.7	22
TBWD	2.2	5.4
TSWD	3.6	6.6
TBC	2.9	6.1
TSC	8.7	19

In summary "working" joint flexibility coefficients spread over the order of magnitude of $10^{\wedge-4}$ rad/Nm in case of joints using Domino connectors for joining beach wood members 40.0 to 41.5 mm wide in the plane of bending. Around double of this value can be accounted for as the secant flexibility coefficient at ultimate load.

Thesis 5: Cyclic bending tests prove that joints of all tested types preserve their original strength after the completion of loading at 25% and 50% load level, and the first cycle of 75% load level based on deflection at ultimate load in static bending. The start of disintegration of the joining members can be accounted in the course of repeated cycles at 75% load level. Further load cycles lead to separation of the joining members in the case of joints with Domino wood dowel. In contrast, dismountable joints do not let the members separate after the test, allowing further functioning. This proves the superiority of dismountable Domino-type joints in dynamic loading.

Thesis 6: Big size joints under sustained loading exhibit significantly higher creep than their small-size counterparts, despite the fact that big-size joints are stronger than small size ones. At the end of the seven days loading period, no systematic difference can be traced with respect to connector type. L. or T joint configuration. Average creep factors after the first 24 hours range between 0.17 and 1.25 while at the end of the sustained loading test between 0.56 and 2.23.

Thesis 7: Logarithmic functions of the form

$$y = a \cdot \ln(t) + b$$

can be fitted on the creep factor data with high value of the coefficient of determination. The coefficient a in the equation as a measure of the initial creep rate is higher in the case of big-

size specimens. This is reflected in the creep curves. The coefficient is also higher with T-joints with the exception of the TSC joint group of exceptionally high scattering of creep data.

Thesis 8: Creep test results expressed as the increase of the joint's flexibility (Z rad/Nm) do not depend on the initial deflection of test pieces. These increments related to the initial "working" value of joint flexibility as well as to the secant flexibility of the same type are indicators of the joints' creep behavior. The ratios of increment to initial value are higher in the case of big-size joint types. In the case of big-size samples, corner joints produce higher increase of the Z-value than T-joints do. The increase of the Z-value of joints with wood dowel is higher than that of similar joints with metal connectors. This is a further proof of the superiority of joints with metal connectors in sustained loading.

These statements are confirmed when the Z-value increments due to creep are related to the secant valuesobserbved at ultimate load in static bending.

Thesis 9: In summary, we can state that the increase of the rotation/moment ratio of the tested Domino-type joints in the course of 7 days sustained loading may attain more than 10 times of the initial value. The increase of the secant ratio experienced at maximum load of static bending test may grow to the double of this value.

The superiority of small-size joint types to big size ones in sustained loading is due to the more favourable positioning of the connecting element in the wooden members with respect to the plane of bending that overmounts the effect of larger size of connector and member cross section.

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SÜRDÜRÜLEBİLİR HİNDİSTAN CEVİZİ ELYAF TAKVİYELİ METİLEN DİFENİL DİİZOSİYANAT REÇİNE BAĞLI POLİMERİK KOMPOZİTLER = (Sustainable Coir Fiber Reinforced Methylene Diphenyl Diisocyanate Resin Bonded Polymeric Composites) In: IV. Ulusal Karadeniz Ormancilik Kongresi: Bildiri Özetlari Kitabi Trabzon, Turkey : Karadeniz Teknik Üniversitesi (2021) 152 p. p. 16 , 1 p.