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A STUDY ON THE IMPACT OF BISCUIT CONNECTORS ON THE STRUCTURAL STRENGTH OF A FURNITURE

Zhao-Jun DENG*
Lecturer - Department of Wood Science and Design, National Pingtung University of Science and Technology
Address: No. 1, Shuefu Rd., Neipu Township, Pingtung County 912301, Taiwan
E-mail: woodzj@mail.npust.edu.tw

Chien-Nan CHEN
Associate Professor - Department of Wood Science and Design, National Pingtung University of Science and Technology
Address: No. 1, Shuefu Rd., Neipu Township, Pingtung County 912301, Taiwan
E-mail: ewnqdx@gmail.com

Hao-Chang TSAI
Associate Trainer –Taichung-Changhua-Nantou Regional Branch, WDA, MOL
Address: No. 100, Gongye 1st Rd., Xitun District, Taichung City 407, Taiwan
E-mail: thj@wda.gov.tw

Chin-Hao CHANG
Assistant Trainer –Taichung-Changhua-Nantou Regional Branch, WDA, MOL
Address: No. 100, Gongye 1st Rd., Xitun District, Taichung City 407, Taiwan
E-mail: q0928815472@gmail.com

Abstract:

As labor shortages and rising wages increase do-it-yourself (DIY) demand, the demand for furniture biscuit connectors rises. Furniture biscuit connectors differ significantly from traditional mortise-and-tenon joints in terms of processing and manufacturing. These connectors help mitigate structural strength issues caused by poor processing.

This study uses MDFs to compare the average load capacity of Lammello #20 wooden biscuits and Clamex P15 connectors. While the two types both meet standard strength required for general furniture, coplanar joint tests show #20 biscuits have a maximum average load capacity of 156 N/mm^2, 46% higher than Clamex P15. In addition, the result of the study indicates that adhesive bonding strength also plays a key role in structural strength. The study provides insights for furniture manufacturing and business strategies to enhance quality and reduce variability.

Key words: *Medium-Density Fiberboard (MDF); Lamello #20; Clamex P-15.*

INTRODUCTION

Furniture design has evolved alongside changes in society and lifestyle, shifting from the fulfillment of basic survival needs toward an integrated pursuit of comfort, functionality, and aesthetics. Its stylistic expressions have also transformed over time, from ornate classical forms to modern minimalism, reflecting both cultural contexts and responses to spatial efficiency and sustainability demands (Kuo 2009, Chen & Chen 2013). In Taiwan, the furniture market presents a dual industrial pattern of standardized mass production and small-scale customization. The former emphasizes efficiency and uniformity (Liang 2021), while the latter highlights craftsmanship and individual value. Despite their differences, both converge on the same core requirement-structural design-which must simultaneously address functionality, durability, safety, and form expression, while also supporting transportation, on-site assembly, and subsequent maintenance (Chen 2015).

Among engineered wood products, Medium-Density Fiberboard (MDF) has become a widely used substrate for panel furniture due to its homogeneity and dimensional stability. However, its edge-holding capacity and resistance to splitting are highly dependent on design and processing parameters, such as edge distance, machining accuracy, and material thickness. These factors often determine the consistency and reliability of joints, particularly in ready-to-assemble (RTA) furniture (Fig. 1), where the standardization of connectors is crucial to ensuring quality and reducing assembly time (Chen 2015).

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*Corresponding author


a.


b.

Fig. 1.
RTA (Ready-to-Assemble) Furniture
a- Parts View; b- Assembled View.

In MDF applications, two common types of coplanar joints are Lamello #20 biscuits, which rely on adhesive bonding and fiber interlocking, and Clamex P15 connectors, which achieve clamping through structural form while allowing repeatable disassembly, fast assembly, and maintenance friendliness. From a market and usage perspective, demountable connectors address demands for mobility, reusability, and waste reduction (Saar et al. 2015), whereas screw fastenings remain advantageous in mass production due to their strength and cost efficiency (Cheng 2009).

Nevertheless, the comparative performance of coplanar and non-coplanar joints in MDF, under identical substrates and geometrical configurations, has a direct impact on assembly quality and durability. Existing literature offers limited systematic comparisons regarding their bending moment resistance, leaving an important knowledge gap in understanding the structural behavior of these connection types.

OBJECTIVE

Building upon the above context, this study investigates the bending moment resistance of coplanar and non-coplanar joints in MDF, using Lamello #20 biscuits and Clamex P15 connectors as the primary subjects. Furthermore, statistical analysis software was employed to evaluate the significance of the observed results.

The research is structured around three main aspects:

1.Evaluation of the influence of MDF on the bending moment resistance of connectors and biscuits under coplanar and non-coplanar configurations.
2.Statistical analysis of the bending moment resistance of connectors and biscuits in coplanar and non-coplanar joints.

MATERIALS AND METHODS

Materials

Medium-Density Fiberboard (MDF)

In this study, commercially available MDF (Fig. 2) with a thickness of 18 mm was selected as the primary testing material. In considering the influence of the basic properties of wood-based panels on bending moment resistance, the MDF used in this study was evaluated in accordance with the CNS 9909 standard. MDF offers advantages such as structural uniformity, stable density distribution, and good machinability, which help eliminate the variability inherent in natural wood due to growth conditions. These characteristics make MDF a reliable substrate for evaluating the performance of furniture connectors.

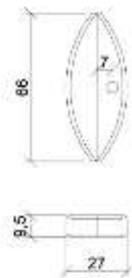
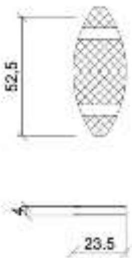
The fundamental properties assessed in this study included density, moisture content, and static bending strength, all determined following the procedures specified in CNS 9909. The measured properties of the MDF are presented in Table 3.

Fig. 2.
Medium density fiberboards.

Connectors

Table 1

Commercially Available Hardware Connectors and Wood Joint (Unit: mm)

Model	Illustration	Specification (mm)
Hardware Connectors Clamex P15		
Wood Joint Lamello #20		

Adhesive

Titebond-TR yellow aliphatic resin glue, produced by one of the largest woodworking adhesive manufacturers in the United States, is regarded as a first-generation standard wood adhesive. The glue has a light-yellow, wood-like appearance, and the dried adhesive film closely resembles the natural color of wood, making the glue line nearly invisible after bonding. It features low viscosity, which allows for easy application by brushing, and is suitable for both cold pressing and hot pressing. Once dried, the adhesive film can be sanded smoothly without clogging the sandpaper (a common issue with white glues that reduces sanding efficiency).

Its normal bonding strength reaches approximately 4000 psi, which is about twice the strength of conventional white glues (≈ 2000 psi), making it particularly suitable for bonding hardwoods in dry environments. In addition, it maintains good workability under low winter temperatures and can be used effectively at temperatures above 5°C (whereas white glue often fails below 15°C).

The required pressing time for Titebond-TR is around 10-15 minutes, which is roughly half the typical pressing time of white glue (20-30 minutes), making it well suited for mass production in system furniture manufacturing.

Testing Equipment

Mechanical testing was conducted using a Shimadzu Autograph AG-10T universal testing machine (Shimadzu Corporation, Kyoto, Japan).

The AG-10T is equipped with a maximum load capacity of 10 kN, a high-precision load cell, and a servo-controlled drive system that enables stable crosshead movement. This machine is commonly used for tensile, compression, and bending tests, providing reliable force-displacement measurements with high accuracy.

Fig. 3.
Autograph AG-10T Universal Testing Machine.

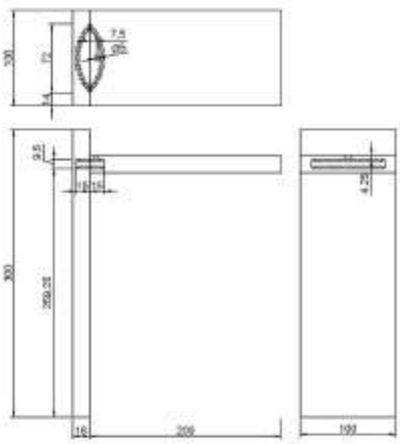
Method

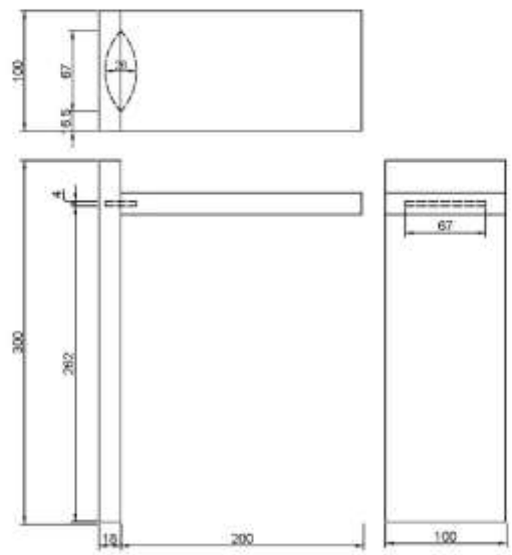
Through the selection of appropriate materials and precisely defined dimensional standards, consistency of specimens and accuracy of test data were ensured throughout the experimental process. A comprehensive analysis was conducted on the slot dimensions of medium-density fiberboard (MDF) in combination with Lamello #20 biscuits and Clamex P15 connectors (Table 2), in order to examine how the fundamental properties of the substrate influence joint strength. Furthermore, the performance of Lamello #20 biscuits and Clamex P15 connectors in MDF was evaluated under both coplanar and non-coplanar configurations (Fig. 4).

For the bending moment resistance tests, the prepared specimens were positioned in a specially designed test fixture (Fig. 5) that enabled accurate measurement of joint performance under specified conditions, thereby providing insight into their effectiveness in practical applications.

Table 2

Dimensions of Slots for Hardware Connectors and Dowels in Co-planar Test Materials

Type of Connector	Orthographic Projection (mm)
Hardware Connectors Clamex P15	

Wood Joint Lamello #20	

a. **b.**

Fig. 4.
Assembly Methods for Bending Resistance Testing of Hardware Connectors and Wood Joint
a-Coplanar Joint; b- Non-coplanar Joint.

a. **b.**

Fig. 5.
Fixation Method of the Bending Moment Resistance Test Fixture
a-Coplanar Joint; b- Non-coplanar Joint.

Testing Procedure

The prepared specimens were assembled according to the slot dimensions with their corresponding connectors or biscuits. Each specimen was positioned in the universal testing machine using a compression setup (Fig. 6). A loading rate of 5 mm/min was applied until failure occurred. The maximum load (P) was recorded, and the maximum bending moment resistance was calculated by multiplying P by the lever arm of 115 mm.

This analysis was conducted to accurately identify the differences in joint performance in MDF and to provide a solid scientific basis for improving the overall performance and durability of wood-based structures. The outcomes of this study are expected to serve as an important reference for the design and practical application of wooden structures.

$$B = P \times L$$

where: B : Bending moment resistance (kgf·mm);
P : Maximum load (N/mm²);
L : Lever arm (mm).

Each test group was repeated ten times. The total number of specimens was determined by the combination of connector type, joint configuration, and repetitions, i.e., 2 × 2 × 10 = 40 specimens.

Fig. 6.
Bending Moment Resistance Test for Co-planar and Non-co-planar Wooden Panel Test Materials.

Statistical Analysis

The experimental data obtained from each test were processed and visualized using Microsoft Excel to illustrate the relationship between bending moment resistance and joint configuration, as well as to analyze differences in structural stability. Subsequently, SPSS statistical software was employed to perform mean comparison tests in order to determine the significance of the effects of each variable on bending moment resistance.

RESULTS AND DISCUSSION

Results

Fundamental Properties of Medium-Density Fiberboard (MDF)

To establish the baseline material characteristics used in the bending moment tests, the MDF specimens in this study were evaluated according to the CNS 9909:2024 standard.

The following material properties were determined in accordance with the required test procedures:

1. Density - measured following Section 7.4 of CNS 9909 using a 100 × 100 mm specimen.
2. Moisture Content - determined according to Section 7.5, by oven-drying the sample at 103 ± 2°C to constant mass.
3. Static Bending Strength (MOR) - tested according to Section 7.6, using a three-point bending setup with a span 15 times the specimen thickness and a loading rate of approximately 10 mm/min.

The measured baseline properties of the MDF are summarized in Table 3, showing a density of 0.57 ± 0.002 g/cm³, a moisture content of 7.16 ± 0.22%, and a static bending strength of 807.19 ± 27.67 N/mm².

These values indicate that the MDF used in this study meets the general requirements specified in CNS 9909 and provides a consistent mechanical basis for the subsequent joint bending-moment resistance tests.

Table 3

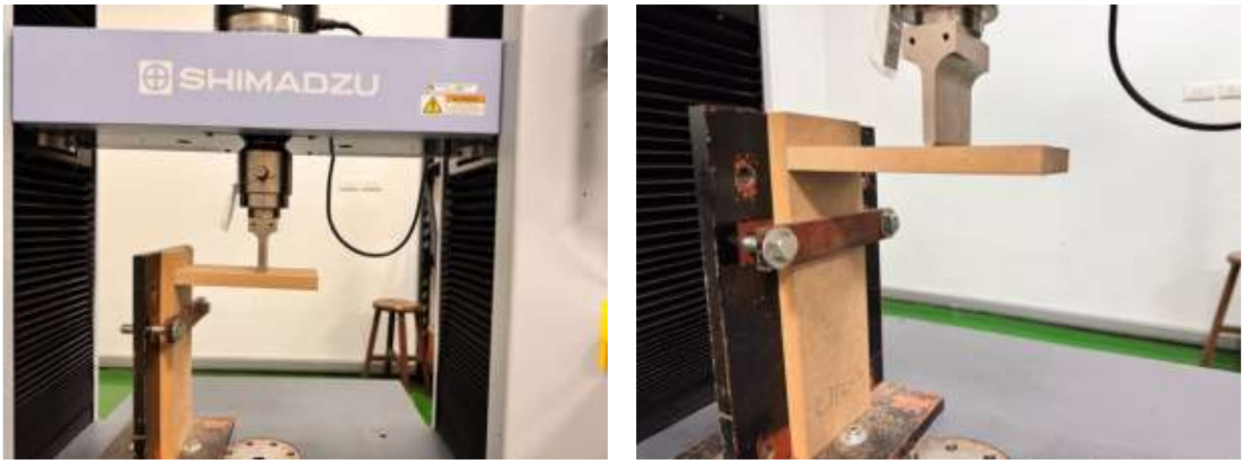
Fundamental Properties of the MDF

Density	Moisture Content (%)	Static Bending Strength (N/mm²)
0.57±0.002	7.16±0.22	807.19±27.67

Effect of MDF Joint Types on Coplanar and Non-Coplanar Bending Moment Resistance

This experiment evaluated the performance of Clamex P-15 connectors and Lamello #20 biscuits under both coplanar and non-coplanar joint configurations (Fig. 7.). The specific results are as follows.

Influence of MDF on the Bending Moment Resistance of Connectors and Biscuits in Coplanar Joints. In the coplanar configuration, the Lamello #20 biscuit exhibited the highest bending moment resistance, exceeding that of the Clamex P-15 connector by 154.6%.



a. **b.**

Fig. 7.
Co-planar Bending Resistance Test for Medium Density Fiberboards
a – Setup of the coplanar bending resistance test for MDF joints using the Shimadzu Autograph AG-10T universal testing machine; b – Detailed view of the loading configuration applied to the MDF specimen during the coplanar bending test.

Table 4

Effect of Connectors and wood joint on the Coplanar Bending Moment Resistance of MDF

Assembly Type	Number of Specimens	Average bending moment capacity (N/mm²)	Standard Deviation (N/mm²)	Standard Error (N/mm²)
Wood Joint Lamello #20	10	156.436±17.97	17.97	5.68
Hardware Connectors Clamex P15	10	61.44±5.07	5.07	1.60

As shown in Fig. 8, the Lamello #20 joints demonstrated a significantly higher bending moment capacity than the Clamex P-15 connectors under the coplanar configuration. The Lamello #20 achieved an average capacity of 156.43 ± 17.97 N/mm², while the Clamex P-15 reached only 61.44 ± 5.07 N/mm². A one-sample t-test confirmed that this difference was highly significant ($p < 0.001$), indicating that the biscuit joint provides a substantially more efficient load-transfer mechanism than the hardware connector in coplanar MDF joints.

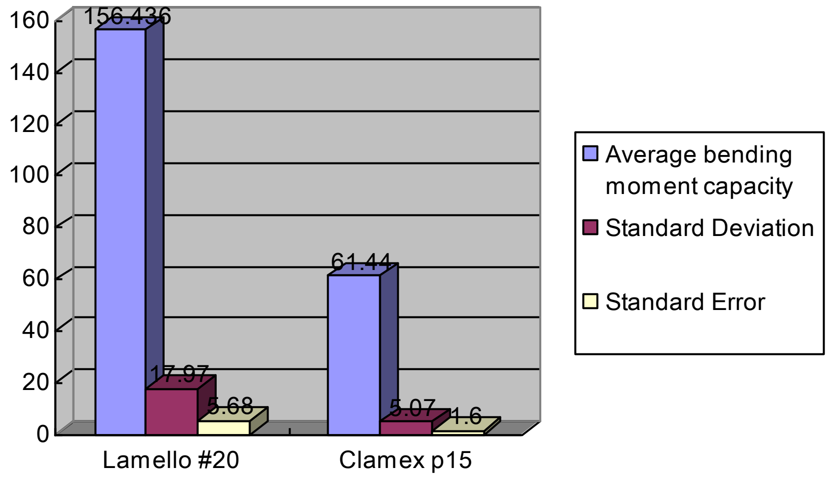
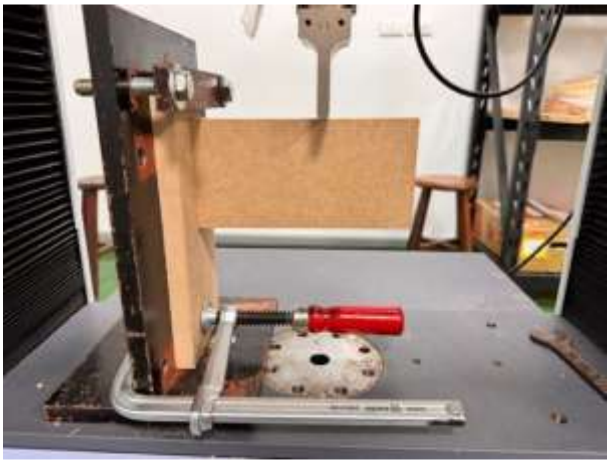


Fig. 8.
Average Bending Moment Capacity of Coplanar MDF Joints.

Effect of MDF Non-Coplanar Joints on Bending Moment Resistance

The test results of different connectors and biscuits in non-coplanar MDF joints (Fig. 9.) are summarized in Table 5. Under the non-coplanar configuration, the Lamello #20 biscuit exhibited the highest bending moment resistance, exceeding that of the Clamex P15 connector by 39.3%.


a.

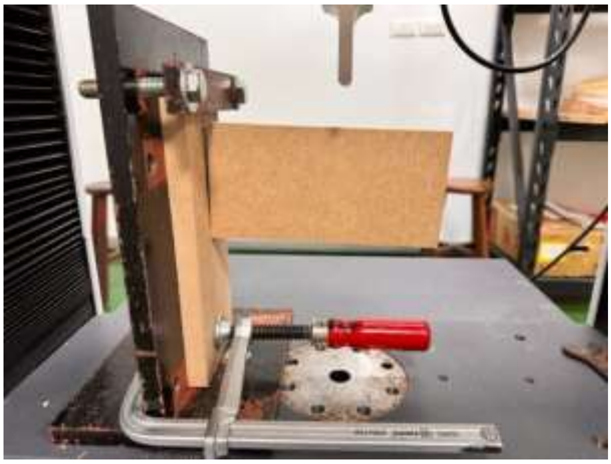

b.

Fig. 9.
Non-Co-planar Bending Resistance Test for Medium Density Fiberboards
a – Setup of the non-coplanar bending test; b – Close-up of the loading configuration.

Table 5
Effect of Connectors and wood joint on the Non-Coplanar Bending Moment Resistance of MDF

Assembly Type	Number of Specimens	Average bending moment capacity (N/mm²)	Standard Deviation (N/mm²)	Standard Error (N/mm²)
Wood Joint Lamello #20	10	717±85.95	85.95	27.18
Hardware Connectors Clamex P15	10	514.83±36.21	36.21	11.45

As shown in Fig. 10, the Lamello #20 joints exhibited a considerably higher average bending moment capacity than the Clamex P-15 connectors. Specifically, the Lamello #20 reached 717 ± 85.95 N/mm², whereas the Clamex P-15 achieved 514.83 ± 36.21 N/mm². Statistical analysis further confirmed that this difference was highly significant ($p < 0.001$), indicating that connector type has a decisive influence on the non-coplanar bending performance of MDF joints.

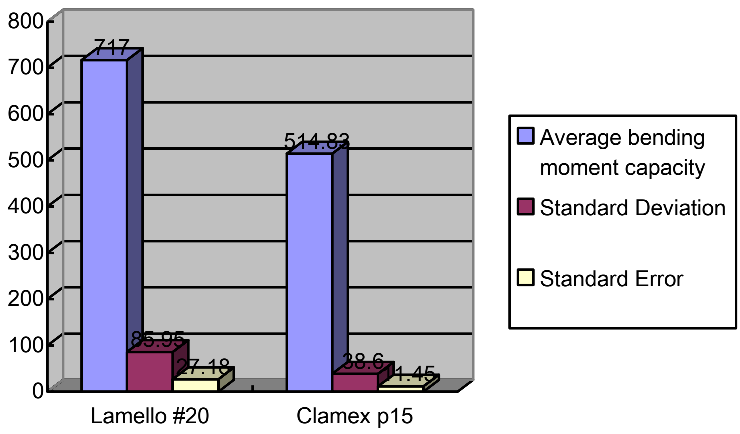


Fig. 10.
Average Bending Moment Capacity of Non-Coplanar MDF Joints.

CONCLUSIONS

This study employed medium-density fiberboard (MDF) as the substrate to empirically compare the bending moment resistance of Lamello #20 biscuits and Clamex P15 connectors under both coplanar and non-coplanar configurations, while also examining the consistency of the results. Overall, the joint configuration was identified as the primary factor influencing performance. In both connector types, shifting from a coplanar to a non-coplanar geometry significantly increased bending moment resistance.

First, the non-coplanar configuration outperformed the coplanar configuration overall. In terms of bending moment resistance, the Lamello #20 biscuit increased from 156.43 ± 17.97 N/mm² (coplanar) to 717 ± 85.95 N/mm² (non-coplanar), representing an improvement of approximately 358.3%. Similarly, the Clamex P15 connector improved from 61.44 ± 5.07 N/mm² to 514.83 ± 36.21 N/mm², an increase of about 753% (Tables 4 and 5). This substantial enhancement indicates that the non-coplanar geometry establishes more favorable load paths and lever arms, distributing stresses over a wider structural domain and reducing the risk of localized edge failure in MDF.

Second, under the coplanar configuration, the Lamello #20 biscuit clearly outperformed the Clamex P15 connector, with an average bending moment resistance of 156.43 N/mm²-approximately 154.6% higher than that of the Clamex P15. This result is particularly relevant for applications requiring concealed joints with adhesive bonding, such as flush panel-to-panel joints with high aesthetic requirements, highlighting the material compatibility between MDF and Lamello #20 biscuits. Conversely, in the non-coplanar configuration, the performance gap narrowed: the Lamello #20 biscuit and Clamex P15 connector achieved average bending moment resistances of 717 ± 85.95 N/mm² and 514.83 ± 36.21 N/mm², respectively. The biscuit exceeded the connector by only about 39.3%, suggesting that the Clamex P15 is more sensitive to joint geometry, and under non-coplanar design can approach the performance of the biscuit while maintaining advantages in disassembly and repairability.

In summary, the alignment between joint type and joint configuration represents a key strategy for achieving both high load-bearing capacity and reliability in MDF-based constructions. When design or aesthetic requirements necessitate coplanar joints, Lamello#20 biscuits provide a distinct performance advantage. In contrast, adopting non-coplanar configurations substantially improves the performance of both joint types, with particularly notable gains for the Clamex P15 connector, which also offers enhanced consistency and ease of maintenance. These findings provide concrete design implications for joint configuration and structural optimization in MDF-based panel furniture.

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