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# INFLUENCE OF DOWEL DIAMETER AND CURING TIME ON STRENGTH OF DOUBLE DOWEL JOINT

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## ABSTRACT

The tensile and bending strength of double wood dowels in medium density fiberboard components was tested by using experimental method which was conducted to define the influence of dowel diameter and curing time on tensile and bending strength of T-shaped and L-shaped double wood joints. The results showed that the dowel diameter and curing time have a great effect on the tensile and bending strength of T-shaped and L-shaped double wood joints. The obtained optimum technical parameters were respectively as follow: dowel diameter was 10.00 mm for tensile strength of T-shaped joints, dowel diameter was 10.00 mm for bending strength of T-shaped and L-shaped joints, and curing time was 168 h for bending strength of T-shaped and L-shaped joints. The relational expression between dowel diameter R and the tensile strength P was obtained in P= 159.7R+11.05, the relational expressions between dowel diameter R and the bending strength P were obtained in P= 30.7R-58.21 and P= 25.48R-41.04 for T-shaped and L-shaped double wood joints, respectively. Moreover, the relational expression between curing time T and the bending strength P in the P= $-0.003T^2+0.683T+164.1$ and P= $-0.003T^2+0.746T+132.0$ for T-shaped and L-shaped double wood joints, respectively.

KEYWORDS: Dowel diameter, curing time, double dowel joint, medium density fiberboard, tensile strength, bending strength.

## INTRODUCTION

Dowel joint was usually used in both solid wood and panel furniture for guiding and positioning purpose with eccentric connection part for further assembly without the use of jigs, meanwhile it also could be used as connection part (Eckelman et al. 2002). The technological parameters were selected according to experience rather than scientific standards in many furniture enterprises, which is likely to result in the failure of furniture structure and the waste of material (Chen et al. 2017).

Dowel joint that made of wood and used with wood-based panels have been studied, and the influence of parameters such as dowel diameter, dowel embedment depths, dowel spacing and curing time after glue sizing on the furniture structural properties such as bending and tensile strength was examined.

The bending strength and tensile strength of dowel joint was increased gradually with the dowel diameter and the embedment depth increasing (Zhang and Eckelman 1993, Dong and Shao 2007, Norvyadas et al. 2005, Sawata and Yasumura 2002). Experiments have shown that maximum moment under compression and tension loads is obtained in 32-mm case construction joints when the spacing between dowels is at least 96 mm (Tankut 2005). Moreover, the influence of glue added to the dowel joint surface on the structural properties was also investigated, and the results indicated that with glue added to the joint area, joints exhibited a constructed strength that exceeded the bonding strength of the board itself. Other studies have found that the influence of glues and additives used on joint surface on tension and bending strength of joints, which found that design of joints and type of glues could affects joint performance (Bardak et al. 2017, Chen et al. 2014). The influence of basic material on the performance of dowel joints connection was also determined, which showed that dowel joints constructed with red oak and plywood had higher bending strength, and those with the particleboard showed the weakest bending resistance (Zhang et al. 2001). Joints made with dowels of beech had higher resistance than dowels of Hornbeam, which showed that dowel made of different wood species could also influence the joint properties, too (Dalvand et al. 2014, Bakar et al. 2017).

## MATERIAL AND METHODS

The scheme of specimen used for tensile strength and bending strength in studies is presented in Figs. 1 and 2. Construction of the specimen consists of two structural parts: a face member and edge member, joined together by two wood dowels. The two structural parts made from medium density fiberboard (MDF) of 18 mm in thickness were joined with 6, 8 and 10 mm diameter dowels, which were made of Japanese white birch wood. The average moisture content, density and modulus of elasticity (MOE) of the birch wood dowels were determined to be 12.93 %, 0.62 $g \cdot cm^{-3}$, and 5090 MPa, respectively. Meanwhile, the 18 mm-thickness MDF used in this study was purchased from Chengdu, China, and the moisture content, density, and MOE of the MDF were 7.4 %, 0.71 $g \cdot cm^{-3}$, and 3035 MPa, respectively.

The two structural parts of specimens were joined together with 45 % solid content polyvinyl acetate adhesive, while viscosity is 12.5 Pa•s. The specimens were tested after one week standing time when two structural parts were joined for the test of influence of dowel diameter on tensile and bending strength of L-shaped and T-shaped joints. All the specimens were tested by loading continued at 10 $mm \cdot min^{-1}$ rate until a non-recoverable drop-off in load occurred, and tests were conducted by using a Reger microcomputer-controlled electronic universal testing machine (Shenzhen Reger Instrument Co., Ltd. Shenzhen, China).

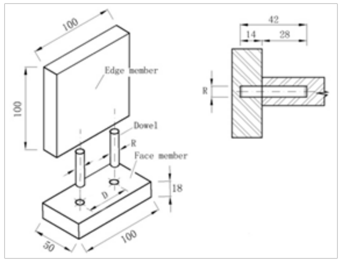
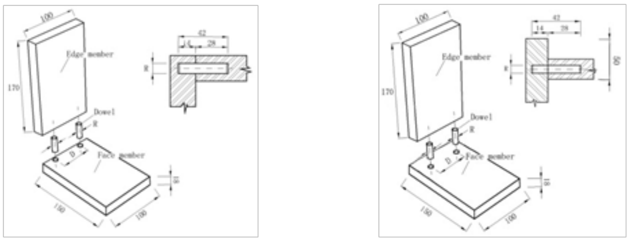



*Fig. 1: Specimen scheme for tensile strength test for double dowel T-shaped joint.*




a b

*Fig. 2: Specimen schemes for bending strength of L-shaped (a) and T-shaped (b) joints.*

## RESULTS AND DISCUSSION

The investigation of the influence of dowel diameter on tensile of T-shaped double wood joints and bending strength of T-shaped and L-shaped double wood joints was carried out by using joints constructed of medium density fiberboard of 18 mm in thickness connected with two wood dowels with diameter of 6, 8 and 10 mm, as shown in Fig. 1 and Fig. 2.

*Tab. 1: Statistical table of influence of dowel diameter on tensile strength for double dowel T-shaped joint test.*

| Dowel diameter (mm) | 6 | 8 | 10 |
|---|---|---|---|
| Specimen 1 (KN) | 981.58 | 1437.72 | 1356.00 |
| Specimen 2 (KN) | 960.64 | 1219.43 | 1746.00 |
| Specimen 3 (KN) | 789.40 | 1537.12 | 1437.00 |
| Specimen 4 (KN) | 1008.00 | 1382.41 | 1521.00 |
| Specimen 5 (KN) | 975.47 | 1418.44 | 1721.00 |
| Specimen 6 (KN) | 892.43 | 1161.64 | 1661.00 |
| Mean value | 934.58 | 1.359.46 | 1.573.67 |
| Standard deviation | 81.00 | 141.73 | 159.91 |

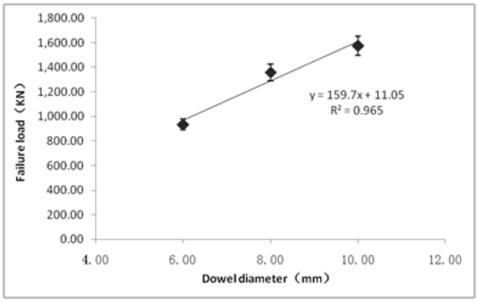



*Fig. 3: Influence of dowel diameter on tensile strength for double dowel T-shaped joint.*

As shown in Fig. 3, there exists a positive linear correlation between doweldiameter and tensile strength for double dowel T-shaped joints from 6-10 mm indowel diameter, which are similar to those of other observations and studies (Dalvand et al. 2014, Hussin et al. 2017). When the dowel diameter was 10 mm, the values of tensile strength reached the peak of 1573.67 N, which was also shown in Tab. 1. Regression equation was derived as follows: P=159.7R+11.05.

*Tab. 2: Statistical table of influence of dowel diameter on bending strength for double dowel T-shaped joint test.*

| Dowel diameter (mm) | 6 | 8 | 10 |
|---|---|---|---|
| Specimen 1 (N) | 134.84 | 175.88 | 271.36 |
| Specimen 2 (N) | 143.22 | 193.08 | 246.43 |
| Specimen 3 (N) | 116.50 | 186.47 | 204.15 |
| Specimen 4 (N) | 129.55 | 178.39 | 271.36 |
| Specimen 5 (N) | 120.90 | 190.04 | 259.63 |
| Specimen 6 (N) | 119.89 | 182.58 | 248.74 |
| Mean value | 127.48 | 184.41 | 250.28 |
| Standard deviation | 10.27 | 6.68 | 24.98 |

*Tab. 3: Statistical table of influence of dowel diameter on bending strength for double dowel L-shaped joint test.*

| Dowel diameter (mm) | 6 | 8 | 10 |
|---|---|---|---|
| Specimen 1 (N) | 128.98 | 160.92 | 203.32 |
| Specimen 2 (N) | 112.48 | 170.02 | 211.89 |
| Specimen 3 (N) | 93.80 | 147.40 | 186.77 |
| Specimen 4 (N) | 104.49 | 178.39 | 224.46 |
| Specimen 5 (N) | 134.00 | 154.10 | 248.74 |
| Specimen 6 (N) | 101.58 | 158.10 | 211.89 |
| Mean value | 112.56 | 161.49 | 214.51 |
| Standard deviation | 15.92 | 11.16 | 20.88 |

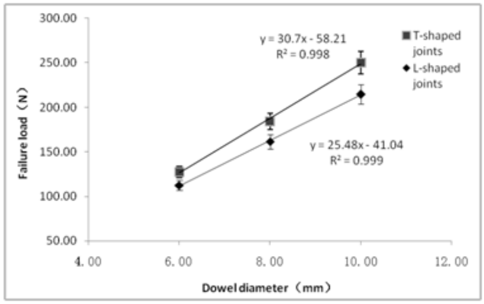



*Fig. 4: Influence of dowel diameter on bending strength for double dowel T-shaped and L-shaped joint.*

As shown in Fig. 4, the results showed that there exists a positive linear correlation dowel diameter on bending strength both in double dowel T-shaped and L-shaped joints, and the dowel diameter have a great effect on the bending strength (Qu et al. 2017, Yun et al. 2017). The bending strength presented an overall trend of increase with increasing dowel diameter. When the dowel diameter was 10 mm, the values of bending strength of T-shaped and L-shaped joints reached the peak of 250.28 N and 214.51 N, respectively, which was also shown in Tab. 2 and 3. Meanwhile, The values of bending strength of T-shaped joint were higher than the vaules of L-shaped joint under the same conditions with dowel diameter, which could be related to the structural mechanical properties of specimens (Yerlikaya and Aktas 2012, Erdil et al. 2003, Yang et al. 2017). The L-shaped joints are weak with poor mechanical properties, relatively, which may leads toless failure load.

The bending strength regression equations were established with dowel diameter for double dowel T-shaped and L-shaped joints as follows: P= 30.7R-58.21 and P= 25.48R-41.04, respectively.

The investigation of the influence of curing time of glue on bending strength of L-shaped and T-shaped double wood joints was also carried out by using joints constructed of medium density fiberboard of 18 mm in thickness connected with two wood dowels with diameter of 6, 8 and 10 mm.

During the test process, bending strength of L-shaped and T-shaped double wood jointsboth increased gradually along with thecuring time, but then increased slowly and approached to be stabilizing (Yasin et al. 2017). When the curing time was 168 h, the values of bending strengthfor double dowel T-shaped and L-shaped joints reached the peak of 194.72 N and 166.22 N, respectively.

*Tab. 4: Statistical table of influence of curing time on bending strength for double dowel T-shaped and L-shaped joint test.*

| Curing time (h) | T-shaped joint test | | | | | | L-shaped joint test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 18 | 24 | 48 | 72 | 168 | 6 | 18 | 24 | 48 | 72 | 168 |
| Specimen 1(N) | 188.44 | 171.53 | 211.29 | 194.31 | 221.29 | 180.07 | 122.58 | 148.49 | 148.17 | 157.61 | 171.06 | 149.08 |
| Specimen 2(N) | 184.26 | 173.24 | 182.58 | 206.87 | 201.84 | 202.68 | 131.01 | 140.88 | 159.48 | 144.51 | 163.27 | 180.91 |
| Specimen 3(N) | 157.09 | 184.64 | 165.60 | 183.05 | 184.81 | 211.06 | 112.73 | 132.83 | 172.12 | 175.49 | 176.25 | 187.61 |
| Specimen 4(N) | 148.21 | 191.06 | 193.01 | 198.09 | 192.05 | 159.13 | 179.23 | 163.39 | 139.38 | 166.18 | 148.54 | 146.57 |
| Specimen 5(N) | 139.54 | 169.34 | 172.59 | 187.05 | 175.05 | 216.08 | 118.93 | 131.85 | 147.81 | 158.91 | 162.45 | 154.94 |
| Specimen 6(N) | 160.54 | 172.15 | 182.05 | 179.02 | 189.05 | 199.28 | 121.06 | 157.61 | 160.14 | 164.24 | 170.04 | 178.21 |
| Mean value | 163.01 | 176.99 | 184.52 | 191.40 | 194.02 | 194.72 | 130.92 | 145.84 | 154.52 | 161.16 | 165.27 | 166.22 |
| Standard deviation | 19.54 | 8.74 | 16.12 | 10.34 | 15.99 | 21.39 | 24.39 | 12.98 | 11.67 | 10.35 | 9.68 | 18.02 |

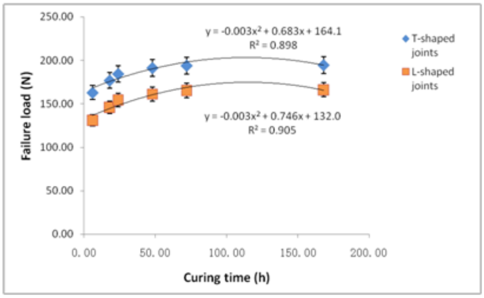



*Fig. 5: Influence of curing time on bending strength for double dowel T-shaped and L-shaped joint.*

When the curing time increased from 6 h to 18 h, the increase value of the bending strength is greater than that of other stages, which shows that the curing rate of polyvinyl acetate adhesive is the fastest in this period. When the curing time increased from 18h to 72 h, the infiltration and permeation of the glue on the dowel increases continuously, and glue solidified gradually resulting in increased bending strength. When the curing time increased from 72 h to 168 h, the bending strength of specimens has little change and tends to be stable gradually. For the same reason of above research result, the values of bending strength of T-shaped joint were higher than the vaules of L-shaped joint under the same conditions with the curing time.

The bending strength regression equations were derived with curing time for double dowel T-shaped and L-shaped joints as follows: $P= -0.003T^2+0.683T+164.1$ and $P= -0.003T^2+0.746T+132.0$, respectively.

## CONCLUSIONS

1. With the increasing of dowel diameter and curing time, tensile strength and bending strength increases.
2. During the tensile strength of double dowel T-shaped joint test process, when dowel diameterwas 6 mm, the dowel was broken easily and caused low withdrawal resistance. When dowel diameter was 10 mm, the value of tensile strength reached the peak of 1573.67 N, but test specimen failure worst-affected.
3. During the bending strength of double dowel T-shaped and L-shaped joint test process, when dowel diameter was 6 mm, the end face of dowel splitted easily. When dowel diameter was 10 mm, the values of bending strength of T-shaped and L-shaped joints reached the peak of 250.28 N and 214.51 N with best joint performance, respectively. But at the same time, dowel was easy to split.
4. The values of bending strength of T-shaped joint were higher than the vaules of L-shaped joint under the same conditions with dowel diameter and curing time, which indicated that the load of T-shaped joint can be greater. In actual production, T-shaped joint is recommended.
5. When the curing time is 168h, the joint properties of T-shaped and L-shaped joint specimens reach the maximum value.
6. The tensile strength regression equation with dowel diameter for double dowel T-shaped joints was derived as follows: $P= 159.7R+11.05$. The bending strength regression equations were established with dowel diameter for double dowel T-shaped and L-shaped joints as

follows: P= 30.7R-58.21 and P= 25.48R-41.04, respectively. The bending strength regression equations were derived with curing time for double dowel T-shaped and L-shaped joints as follows: $P= -0.003T^2+0.683T+164.1$ and $P= -0.003T^2+0.746T+132.0$, respectively.

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