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MORTISE AND TENON FAILURES IN SCHOOL FURNITURE

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INTRODUCTION

In general, the most critical parts of any furniture are the joints. This fact is portrayed by the results of performance testing whereby the typical sample failures are normally due to joint failures. This article highlights the common causes of joint failures of wooden school furniture, namely chairs and tables. Mortise and tenon type of joint is widely used to assemble school furniture. Good quality mortise and tenon ensures the strength of joints which would result in the overall strength of any furniture. For this type of joint, there are many parameters which will determine its strength, namely: dimension, material, adhesive, workmanship and etc. The characteristics which contribute to failure will be explained herein.

There are many types of mortise and tenon joints, but the three (3) common types are: stopped/blind, through and angled (Stack 2005). For Malaysian school furniture, the stopped/blind type is commonly used as specified by KPM. Generally, all mortise and tenon joints consist of two basic parts, i.e., tenon and mortise as shown in Figure 1.

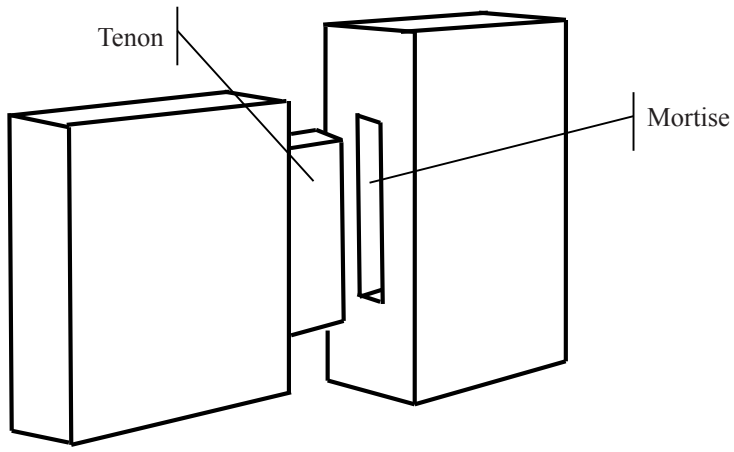

Figure 1 Stopped/blind mortise and tenon joint

TEST METHODS TO EVALUATE JOINT PERFORMANCE

In testing procedure performed at FRIM's Furniture Testing Laboratory (FTL), a piece of school furniture undergoes a series of test sequence in accordance with a specific standard test requirement, namely BS EN 1729-2: 2012+A1:2015 . Some crucial tests which affect the strength performance of school chairs and tables considerably are shown as follows. These following tests are the common ones where the samples normally fail:

1. Chairs

For chairs, there are three critical tests which highly distress the sample structure, namely: seat and back fatigue test, back impact test and drop test.

i. Seat and back durability test

Seat and back fatigue test is the application of a vertical force of 1,250 N (125 kg) on the seat followed by a horizontal force of 300 N (30 kg) on the backrest while the vertical force is maintained as illustrated in Figure 2. This simulates the usage of a chair when a person sits (vertical force) and then leans on the backrest (horizontal force). The test runs for 100,000 cycles.

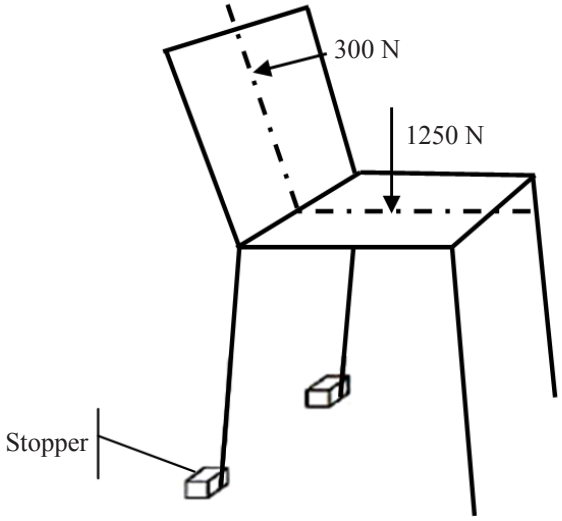

Figure 2 Seat and back fatigue test

ii. Back impact test

In this test, a pendulum hammer of 6.5 kg in weight with a pendulum arm of 1000 mm in length is dropped freely from a specific height, *h,* to strike the centre of top edge of backrest (Figure 3). The test is repeated for 10 times. The height, *h*, for primary school chair is 330 mm and for secondary school chair is 620 mm.

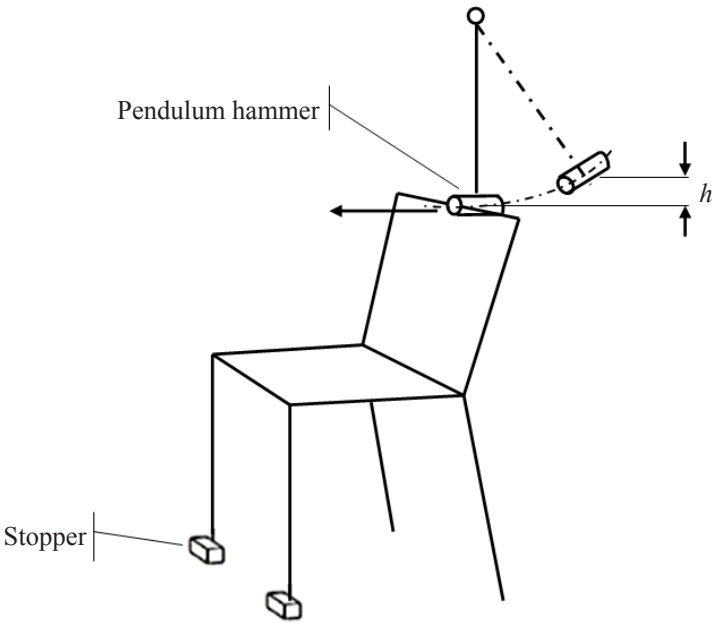

Figure 3 Back impact test

iii. Drop test

In this test, the chair is positioned such that the diagonal line between two legs ends is at an angle of 10° from the horizontal floor. The chair is then raised such the lowest position leg is 600 mm from the floor (Figure 4). The chair is then dropped freely to the floor. The test is repeated five (5) times for one front leg and five (5) times for one rear leg.

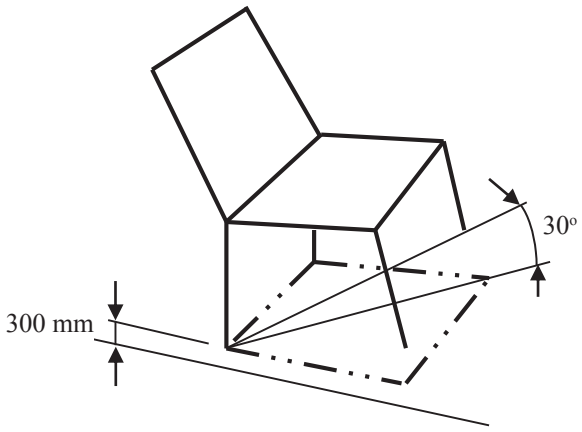

Figure 4 Drop test

2. Table

For tables, failure frequently occurs during horizontal fatigue test, i.e., when horizontal forces of 300 N (30 kgf) each, are applied from four directions alternately at the table top level as illustrated in Figure 5. A dead load of 50 kg is placed at the centre of the table top. The table shall stay rigid and sturdy throughout the test until the 10,000 cycle ends.

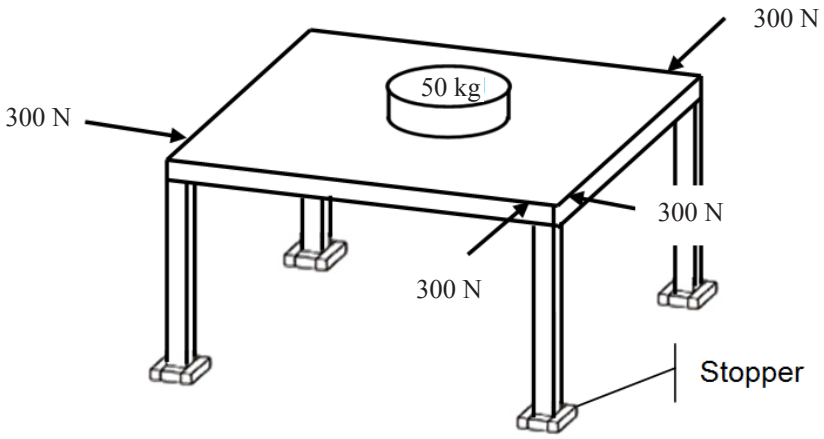

Figure 5 Horizontal fatigue test on a school table

CAUSES OF FAILURE

After the tests, samples which have failed exhibit common failure characteristics such as loosened or detached joint or part breakage. As for joint, i.e., mortise and tenon, there are a few common factors observed from the failed sample as described below:

i. The clearance between mortise and tenon

The visible gap between mortise and tenon is a major flaw in furniture workmanship (Figure 6). It prevents the furniture from having a firm and strong structure from the start. Thus, it is mandatory to keep the gap between mortise and tenon as minimum as possible, close to 0 mm.

Figure 6 A considerably large gap between mortise and tenon is observed from a detached joint

ii. Glue application

Glue keeps a joint from being pulled apart and helps in reducing slippage between mortise and tenon. Well applied glue also helps to distribute stress around joints due to dynamic forces exerted by users. Glue needs to be evenly distributed on the entire contact surface of mortise and tenon with the right amount to ensure the bonding strength between the two is at the optimum level (Prekrat et al. 2010). As a bad example, it can be observed in Figure 7 that the glue application is not properly applied to the joint such that the mortise and tenon can easily be disjointed by little force.

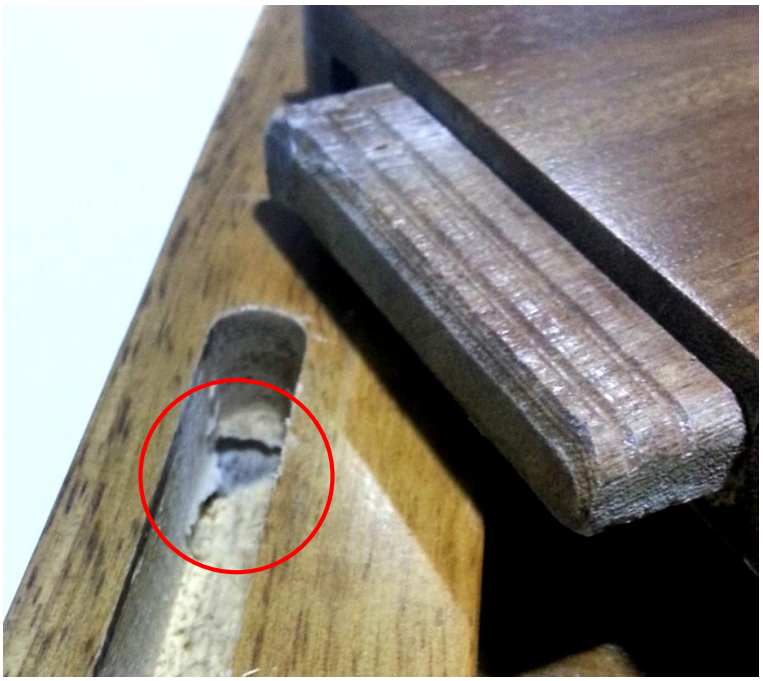

Figure 7 Spot glue is not evenly distributed on the contact surfaces

iii. Dimensions

There is no universal rule for sizing mortise and tenon joint due to its various applications. But the dimensions of the tenon thickness, tenon width and tenon length are the key factors that affect the strength performance of any joint (Kasal et al. 2016) (Figure 8).

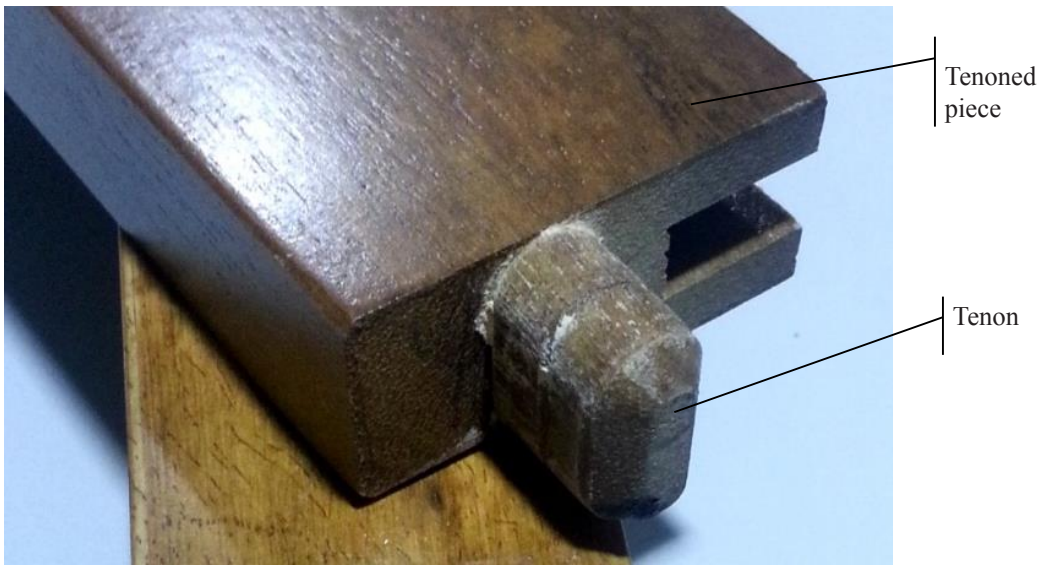

Figure 8 The orientation of tenon thickness and width is improper as compared to the thickness and width of tenoned piece

JOINT ENHANCEMENT

In an effort to enhance the joints strength performance, manufacturers tend to use additional aids such as nail, L-bracket and a series of groove profile on tenon surface (Figure 9). Unfortunately, these elements do not give much of help except that they add up unnecessary production cost. The basic principles of mortise and tenon joint which have been discussed earlier need to be applied first by manufacturers to produce a good quality school furniture. This practice will reduce the possible loss due to joint failure in the short and long term.

Figure 9 The application of nail or L-bracket does not provide significant support on the joint strength if the fundamentals of good mortise and tenon are not fulfilled

In regard to timber properties, mill must undertake control of quality by ensuring that the recommended species and moisture content of timber are followed. Moisture content can be measured using a calibrated moisture meter or, more accurately, using the oven dry method.

CONCLUSION

Mortise and tenon is the common joint type for Malaysian school furniture supplied under government contract. The common failures of this type of joint can easily be avoided by practicing better quality control by the manufacturer. These include the correct species selection, accurate mortise and tenon dimension and orientation and enhancement by correct glue application. Another important factor is the preparation of raw materials whereby the moisture content need to be monitored to achieve the optimum value before commencing the production. Furthermore, the improvement of product quality is also attributed to the competency of the production workers in ensuring the above factors are met.

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The use of mortise and tenon joint in wooden school furniture is one of the specifications outlined by the Kementerian Pendidikan Malaysia (KPM). The manufacturers have to produce good mortise and tenon joints to ensure that the furniture are able to fulfil the performance test. Among factors which contribute to the mortise and tenon failure in the performance tests are the species selection, the dimensions of mortise and tenon, the glue application and the moisture content of the mortised and tenoned pieces.

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