Materials and Design 87 (2015) xxx–xxx

Contents lists available at ScienceDirect

Materials and Design

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

A comparison of the cyclic durability, ease of disassembly, repair, and reuse of parts of wooden chair frames

Mesut Uysal, Eva Haviarova *, Carl Albert Eckelman

Purdue University, Department of Natural Resources and Forestry, West Lafayette, IN 47906, USA

ARTICLE INFO

Article history:
Received 19 February 2015
Received in revised form 28 July 2015
Accepted 2 August 2015
Available online 4 August 2015

Keywords:
Wooden Joints
Reusing
Remanufacturing
Recycling and cyclic load tests

ABSTRACT

Simple, statically-determinate wooden chair frames constructed with seven types of joints were subjected to cyclic front to back load tests to determine joint durability, chair reparability, and parts' reuse. Knockdown joints, namely, screw, bed bolts (with dowel nuts), pinned round mortise and tenon, and pinned rectangular mortise and tenon joints; and glued joints, namely, dowel, round mortise and tenon, and rectangular mortise and tenon joints were included in the study. Glued round and rectangular mortise and tenon joints had the highest levels of cyclic load durability whereas bed bolts had the least. Chairs constructed with knockdown joints were easiest to repair, whereas chairs constructed with glued joints were the most difficult to repair. Parts' recovery with rectangular mortise and tenon joints was high when tenons were replaced with inserted tenons. Likewise, recovery was high with dowel joints since the failed dowels were replaced with larger dowels. Parts' recovery with metal knockdown fasteners was low because of side rail splitting; however, parts' recovery with pinned round and rectangular mortise and tenon joints was high.

1. Introduction

When chairs and tables fail in service, owing to fractured legs and rails, but more often owing to loose or failed joints, they are regularly discarded [5,6]. In affluent areas of the world, replacement of such furniture may be nothing more than an inconvenience but in disadvantaged areas replacement may not be possible [15]. Difficulties in replacement of school furniture in the latter areas are of particular concern since many schools already lack sufficient furniture and replacement of the existing furniture is difficult and slow to occur [14]. Product and part reuse is not a new concept, it has been considered increasingly in remanufacturing of industrial activities since Second World War. Nowadays, benefits of reused parts – reducing energy required and environmental impacts of products in manufacturing [2] – and changing demands in society has caused to increase interest in remanufacturing [8].

It is important, therefore, to determine how furniture should be designed [5] a) to have the longest possible service life, b) to be easily repaired, and c) to have reusable parts so that broken or discarded furniture (that cannot be simply repaired) such as legs, rails, and stretchers can be recycled, i.e., incorporated into a new generation of furniture. Aesthetics, of course, must also be considered and it must be accepted that furniture constructed from recycled parts would not be acceptable in all design situations; however, in a reuse-or-nothing situation, such as school furniture in developing world, new furniture constructed from reused furniture parts seemingly would provide an acceptable if not welcome solution [14,15]. If recycling is to be done efficiently, however, pre-planning for reuse needs to be incorporated into the original design of the furniture.

Overall, the initial life of a chair is usually related to joint failure [5,6]. Hence the cyclic load durability of the joints used in construction of a chair is critical to the initial length of life [5,6]. Ease of repair is largely a function of how easily the chair can be disassembled. In this respect, knockdown joints would be expected to have an inherent advantage over glued joints.

Reuse and recycling of parts are both a function of the damage done to the parts in service and also a function of the amount of material that has been removed from the part to accommodate fasteners such as dowels, tenons, and knockdown fasteners. Materials initially removed for fastening can be filled to satisfy esthetic considerations, but this action does not restore structural integrity to the member. Hence the amount of material that has been removed from a part in construction of a joint plays a decisive role in whether or not a part may be re-used [5,7,16].

Ordinarily, length of service life is one of the most important considerations in the design of furniture, and in most cases, it is a function of joint construction [5,6]. Two questions follow, a) what is the relationship of joint design (type of joint) to load capacity (particularly cyclic load capacity), and b) what is the relationship of joint design to furniture reparability and parts re-usability? To provide insights and useful answers to these questions, the study described below was conducted a) to determine the cyclic load capacity of knockdown and glued joints (in a typical statically determinate frame construction) and b) to determine the nature of the damage associated with the failure of each type of joint and its relationship to frame repair and part reusability.

* Corresponding author.
E-mail address: ehaviar@purdue.edu (E. Haviarova).

http://dx.doi.org/10.1016/j.matdes.2015.08.009
0264-1275/

Numerous studies of static load capacity of joints, such as square and round mortise and tenon, dowel, CAM and other joints, have been conducted [3,10–12,16]. Published information concerning the cyclic performance characteristics of most commonly used wooded furniture joints as well as full frames made with these joints is largely lacking [10]. The purpose of this study was to provide such information. The study objectives are listed below.

1.1. Objectives

a. Determine the cyclic front-to-back load capacity of frames constructed with seven types of joints—and thereby joint capacity.
b. Determine which joints allow for the simplest repair of chairs following failure.
c. Determine which fasteners and connectors are best suited for reconstruction of chairs.

2. Materials and methods

2.1. Design of experiment

The study was carried out in three stages. In the first stage, five frames [9] (Fig. 1a) were constructed with each of seven types of joint

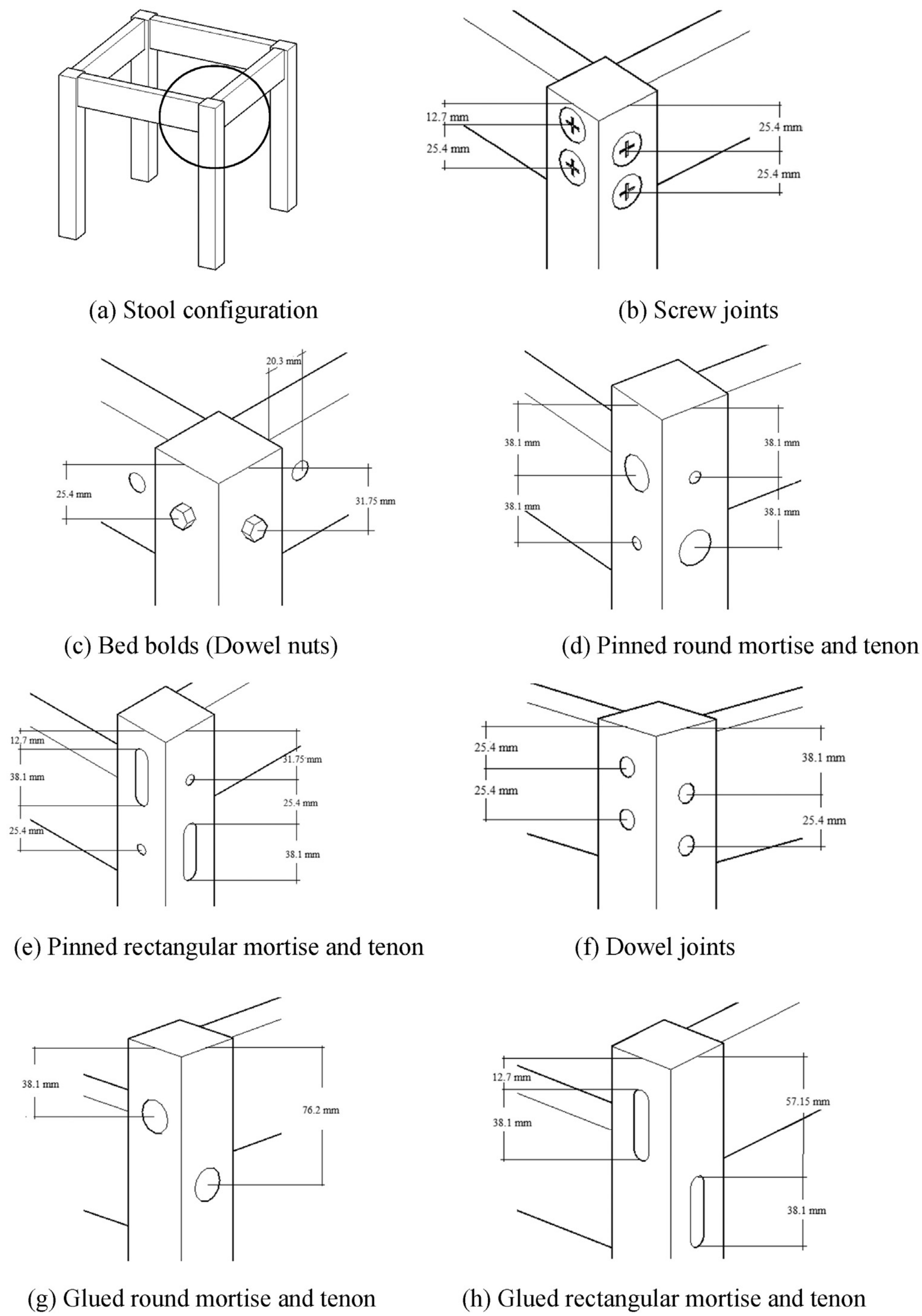

Fig. 1. Stool and joint configuration. (a) Stool configuration. (b) Screw joints. (c) Bed bolds (Dowel nuts). (d) Pinned round mortise and tenon. (e) Pinned rectangular mortise and tenon. (f) Dowel joints. (g) Glued round mortise and tenon. (h) Glued rectangular mortise and tenon.