

Chapter 1 - Introduction

1.1 Introduction

Wood is a highly versatile material and can be used in a wide range of building applications because of such factors as high strength to weight ratio, high stiffness to weight ratio, and economy. However, an expanded scientific understanding of the expected response of a wood structure is required to ensure the safety and competitiveness of wood in the construction market particularly in high wind and seismic areas.

Connections are of vital importance to the safety, integrity, and economy of designs utilizing wood. Bolted connections are a principal method used in the fabrication of structures with timbers and engineered wood products. Knowledge of the behavior of a bolted connection is a key component in understanding and predicting the behavior of the entire structure. Historically, the majority of research has focused on the behavior of connections at working stress limits under monotonic loading and the design of timber connections has been based on empirical methods. Working stress limits correspond to the load applied before permanent deformation occurs in the material. Ultimate limits correspond to a loading condition where permanent deformation occurs in the material. Monotonic loading simulates a sustained static load applied to a structure such as gravity load. In the past it has been assumed that live loads such as wind and seismic would create similar connection behavior as the monotonic loading so testing was not performed for natural hazard loading, which can be simulated by reverse cyclic loading.

Design specifications for wood construction are found in the National Design Specification for Wood Construction (NDS, 2001) which utilizes the Yield Limit Theory. The current recommendations found in NDS for several design details such as bolt spacing are based on research performed in 1932 by George Trayer (1932). He conducted several hundred tests under monotonic loading at working stress limits and produced empirical results which resulted in the current minimum bolt spacing criteria of four times the bolt diameter (4D) for loading parallel to grain utilizing the full design value.

Opportunities for new structural innovations in wood require that the designer have an improved understanding of the actual performance of bolted connections and whether current standards are

optimum for natural hazard loading. Therefore, it is necessary to understand the performance of the connection at yield and at failure under reverse cyclic loading and determine which variables affect the connection performance. This research specifically examines the current practice of spacing bolts in a multiple bolt connection at 4D. Five spacings; 8D, 7D, 6D, 5D, and 3D, are tested and the results are compared to previous research for the 4D spacing to determine if the current design recommendations of spacing bolts at 4D is most optimum for natural hazard loading conditions. This thesis will also provide information to aid in a mechanics-based design method to be developed.

1.2 Objectives

The objectives of this research are:

- 1) To determine if spacing between bolts in a multiple-bolt, single-shear connection subjected to reverse cyclic loading affects seven strength and serviceability parameters: maximum load, failure load, E.E.P. yield load, 5% offset load, elastic stiffness, E.E.P. energy, and ductility ratio.
- 2) To determine if a statistical difference exists between results produced by research completed by Anderson (2002) for 4D spacing as compared to results produced by this research for five other spacings: 8D, 7D, 6D, 5D, and 3D.
- 3) To determine which of the spacings examined by this research; 8D, 7D, 6D, 5D, 3D, produced the most optimal results for each strength and serviceability parameter where optimization is based on economy and performance.
- 4) To generate data so that the model developed by Heine (2001) may be expanded to include the ability to predict the load-slip relationship, energy dissipation, damping characteristics, and failure prediction of multiple-bolt timber connections subjected to reverse cyclic loading. While the data is generated by this research, the actual enhancement of Heine's (2001) model is not performed.

1.3 Significance

This research determines the optimum distance to space bolts in a multiple-bolt, single-shear connection subjected to natural hazard loading. Results of this research can be used to evaluate the current design recommendation presented in the National Design Specification for Wood

Construction (NDS, 2001) of spacing bolts at four times the bolt diameter ($4D$) to determine if a different spacing should be recommended for natural hazard loading conditions.

1.4 Thesis Overview

Chapter two presents the literature review of previous research on multiple-bolt connections subjected to monotonic and reverse cyclic loading with discussion on the development of current design practices and other related research. Chapter three contains a discussion on the procedures and methods used in this research. Chapter four presents the results and discussion of the research and chapter five includes the conclusions and summary of results along with recommendations for future research. Appendix A presents the results for the monotonic testing. Appendix B presents the results for the reverse cyclic testing. Appendix C presents details of the statistical analysis.