

Chapter 1: Introduction

For centuries, buildings all over the world have been constructed utilizing large timbers joined together using various types of wooden joints and secured with wooden pegs and wedges to create structural skeletons that are enclosed to provide shelter and interior spaces as shown in Figure 1.1. Different cultures derived distinct construction methodologies, but all of these buildings using primarily wooden joints are considered timber frames. Timber frame construction has proved to be a dependable and enduring building system. With the advent of industrialization and resulting ease of producing dimensional lumber, light-frame construction became much more common and replaced timber framing as the mainstay of low-rise wooden buildings. Nevertheless, a revival of interest in timber frame building in the United States occurred during the 1970s and since that time, the timber framing industry has grown to keep up with demand for timber frame houses, barns, churches, and other structures (O'Connell and Smith, 1999). European and Asian countries have also kept timber frame construction alive, even as other building methods have become more popular over the past 100 years.

Contemporary timber frame structures, especially in the United States, typically utilize structural-insulated panels (SIPs) attached to the timber frame skeleton to enclose the frame and create a functional structure as shown in Figure 1.2. These panels consist of a layer of rigid insulation that is typically covered on one side by oriented strand board and on the other side by oriented strand board, gypsum drywall, or some other interior finish, such as tongue and groove paneling. Current design methodologies for timber frame structures do not include, in a formalized way, the potential structural benefits of SIPs considered as diaphragm elements.

Lateral forces resulting from wind and earthquakes can induce considerable shear and bending stresses into building components. While timber frame structures are typically well within safety limits with regard to gravity loads, lateral loads can potentially exceed the stress limits of timbers and joints. One area prone to overstress in timber frame structures is the tenon portion of a beam because it is much smaller than the rest of the member, as illustrated in Figure 1.3, and is further limited in strength by holes for the wooden dowels and short edge distance from the dowel holes to the end of tenon.



Figure 1.1. Timber framing shown for a great room near Blacksburg, VA. The nominal timber sizes typically range from 6 in. (154 mm) by 6 in. (154 mm) to 12 in. (305 mm) by 12 in. (305 mm) and common species include Southern Pine, Douglas Fir and Mixed Oak.



Figure 1.2. Contemporary timber frame interior with SIP walls and roof is shown during construction. One inch (25 mm) oak pegs can be seen at the top of 8 in. (203 mm) by 10 in. (254 mm) post. Spacers between timbers and SIPs provide space for installation of drywall on walls and ceiling.

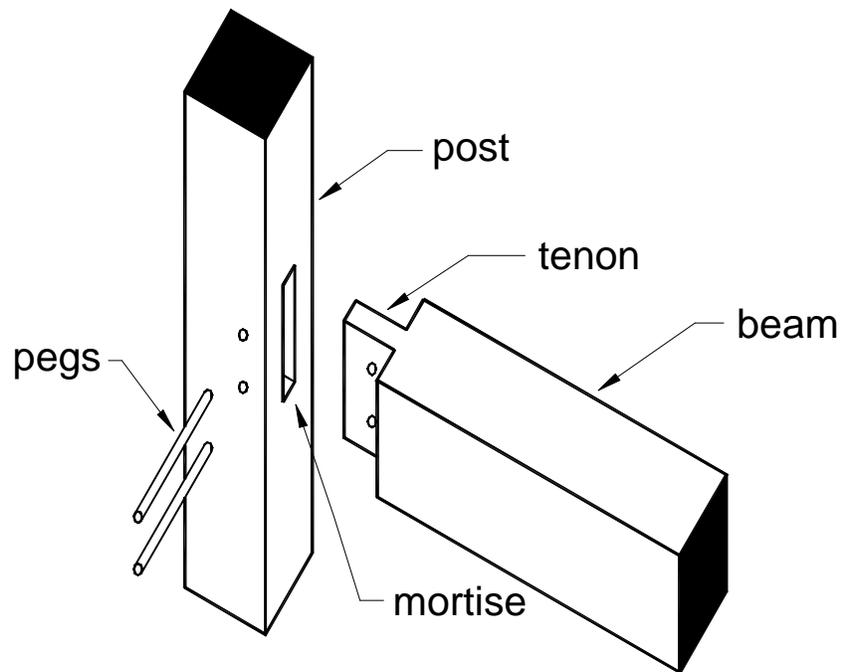


Figure 1.3. Typical elements of a mortise and tenon joint. Pegs are typically 1 in. (25 mm) and tenons are typically 1-1/2 in. (38 mm) thick.

When timber frame structures are loaded laterally under typical wind speeds or seismic ground accelerations, it is very likely that the tenons on members where tension forces are induced will be overstressed if the contribution of the building diaphragms and shear walls are not included in the structural analysis. Timber frame structures have an excellent performance record, and it is therefore assumed that even though the frame alone does not have the strength to resist lateral loads, the contribution of SIPs or other cladding contributes to the ability of these structures to effectively resist lateral loading.

For over twenty years, post-frame structures (Figure 1.4) have been the subject of considerable research aimed at quantifying “the tremendous contribution of the ceiling and/or roof diaphragm and endwalls to the stiffness and strength of the building assembly” (Gebremedhin *et al.*, 1992a). Results have been used to develop a methodology that allows engineers and designers to quickly and easily calculate the forces present within post-frame structural elements and account for the diaphragm action of the roof and endwalls. These advances in diaphragm design have resulted in safer and more cost-effective design of post-frame buildings, which have grown in use from simple agricultural buildings to commercial, residential, institutional and industrial structures (Walker *et al.*, 1992).

The objective of this research was to develop design and test procedures needed by timber frame structural designers to capitalize on diaphragm action of SIPs when designing timber frame structures to resist lateral loads. An analysis of the research leading to current post-frame diaphragm design procedures provided guidelines and strategies that enabled this objective to be met without starting from scratch. An initial investigation (Carradine *et al.*, 2000) indicated that timber frame design could indeed benefit from incorporating the SIPs as part of the lateral force resisting system of the building. The following chapters specify the needs of the design community, laboratory test data needed from tests of roof diaphragm assemblies and shear walls, methods for determining building stiffness from roof test assembly stiffness, and the design procedures required in order to establish safe and cost effective design procedures for timber frame structures. Also described are results of structural roof diaphragm tests conducted and subsequent data analyses. Testing provided critical information on the strength and stiffness of timber frame and SIP roof assemblies and analyses quantified

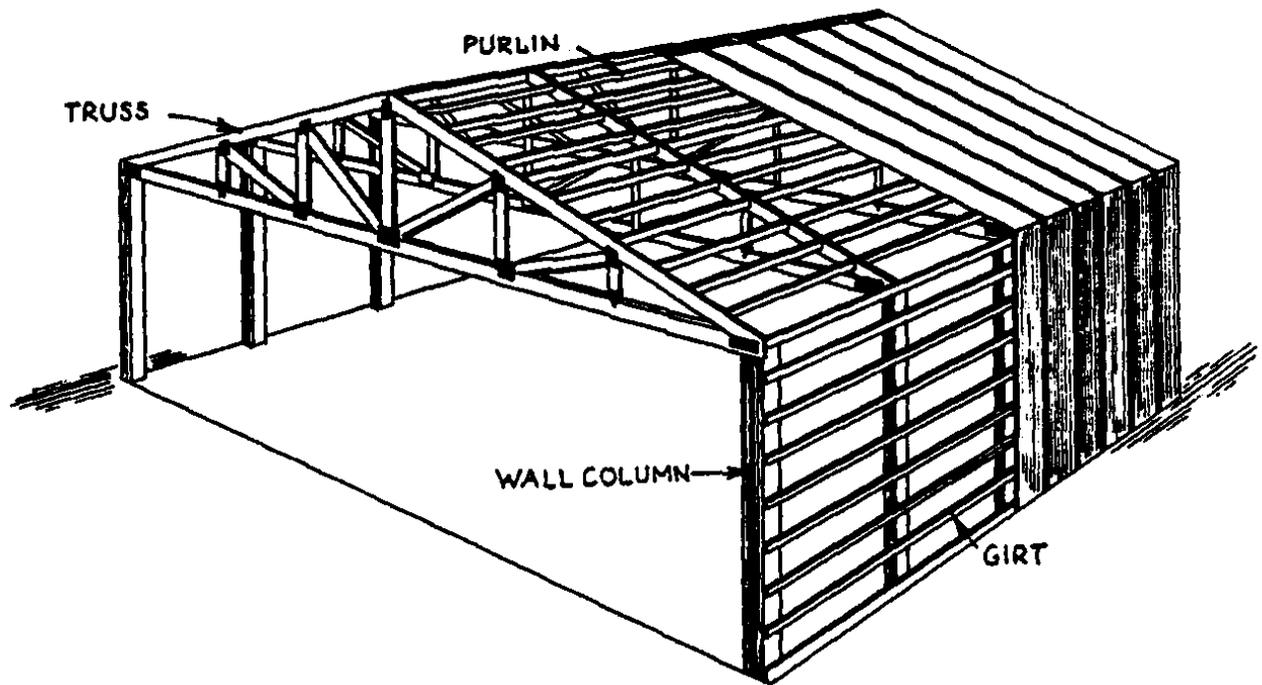


Figure 1.4. Typical post-frame building from Hoyle and Woeste (1989) showing the main structural components of the system. Steel cladding provides the necessary diaphragm stiffness and strength.

the contributions made by SIPs and the timber frames in resisting lateral loads applied to them. This knowledge was incorporated with existing procedures for diaphragm design of post-frame structures in order to develop a similar methodology for the design of timber frame buildings that included the SIPs as diaphragm elements for lateral load resistance.