Methodology for the Design of Timber Frame Structures Utilizing Diaphragm Action

by

David Marc Carradine

Committee Chairs: F. E. Woeste, P. E. and J. D. Dolan, P. E.

Biological Systems Engineering

(Abstract)

Modern timber frame buildings are a unique combination of ancient carpentry techniques coupled with one of the newest enclosure systems found on construction sites around the world. Contemporary timber frame structures typically utilize structural-insulated panels (SIPs) attached to a timber frame skeleton to create functional, enclosed structures, such as houses, churches and a myriad of retail and industrial buildings. The skeleton contains large wooden members connected using wooden joints held together with wooden pegs or wedges. SIPs consist of a layer of rigid expanded polystyrene insulation covered on one side by oriented strand board and on the other side by oriented strand board, drywall, or some other interior finish. In timber frame buildings, SIPs also serve as diaphragm elements, which are flat structural assemblies loaded by shear forces in the plane of the panel. Current design methodologies for timber frame structures do not formally incorporate the structural benefits of SIPs as diaphragm elements, which contribute significantly to the ability of these buildings to resist lateral loads.

The contribution of this research was to quantify necessary design parameters to enable timber frame designers to capitalize on the significant in-plane strength and stiffness of SIPs when designing timber frame structures to resist lateral loads. Strength and stiffness tests were conducted on three 8 ft (2.44 m) deep and 24 ft (7.32 m) long roof diaphragm assemblies, and two 20 ft (6.10 m) deep and 24 ft (7.32 m) long roof diaphragm assemblies. Data from these tests were collected, tabulated and analyzed according to existing methods typically utilized for post-frame diaphragm testing. Strength and stiffness of timber frame and SIP roof diaphragm assemblies were determined from monotonic test results and a value for Response Modification Coefficient, R, for use with seismic design procedures, was estimated utilizing cyclic test data. Procedures for calculating strength and stiffness of a roof diaphragm based on the strength and stiffness of test panels were presented and incorporated within post-frame diaphragm design methods. Diaphragm-frame interaction analyses were performed utilizing test data from roof diaphragm assemblies that demonstrated the code conformance of members within timber frames subjected to lateral loads. Using roof diaphragm test data and procedures developed for adjustments from the test panel to building roof length, example designs were conducted which confirmed the effectiveness of including SIPs as diaphragm elements for code conforming designs for wind and seismic load resistance of timber frame and SIP buildings.