By Thanh Huynh, Dr. Thomas Miller, Dr. Rakesh Gupta

Practical Modeling Methods For Light-Frame Structures

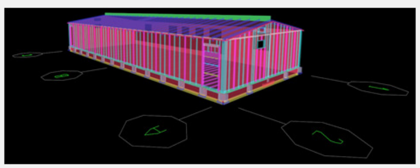
Introduction

Typical engineering design methodology includes the determination of loads on the structure and consequently, the design of members to adequately withstand these loads. There are two essential concepts in design that this modeling method directly addresses.

The first of these is the requirement of a continuous load path so that the structure can adequately transfer any load on a structural element safely into the foundation. Second, system effects in the structure, such as load sharing, also must be included in a practical method.

Wolfe (1998) found that wind was the most common (and costly) cause of damage to all structures in the U.S., resulting in over $41 billion dollars in damage between 1986 and 1993 compared to $6.8 billion, the total for all other natural hazards combined.

Updated codes in response to the destruction caused by Hurricane Andrew (1992) and Hurricane Katrina (2005) have helped to address the risk of damage in newer buildings. However, since a majority of single-family residences were built before these code updates, there still exists a substantial concern for wind damage on light-frame buildings. Moreover, the prevailing source of damage in light-frame structures was because of insufficient strength in the connections to transfer uplift loads.



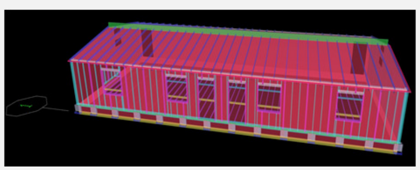


Figure 1a (Top) and Figure 1b (Bottom)

Citations

Datin, P. L. (2009). "Structural Load Paths in Low-Rise, Wood-Frame Structures." Ph.D. Proposal, University of Florida, Gainesville, Florida

Martin, Kenny G. *Evaluation of System Effects and Structural Load Paths in a Wood-Framed Structure*. Thesis. Oregon State University, 2010. Corvallis: Oregon State U, 2010. Print.

Nairn, John A. *OSULaminates*. Crovallis: Oregon State University, 18 Nov. 2011. JAR.

Pfretzschner, Kathryn S. *Practical Modeling for Load Paths in a Realistic, Light-Frame Wood House*. Thesis. Oregon State University, 2012. Corvallis: Oregon State U, 2012. Print.

Wolfe, R.W. (1998). "Wind Resistance of Light-Frame Structures." Proceedings of the third wood building/architecture technical seminar. Seoul, Korea.

LATERAL LOAD PATH ANALYSIS

Practical Modeling Methods For Light-Frame Structures

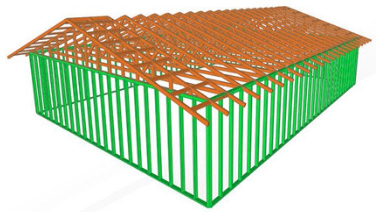


Figure 2a (Top) and Figure 2b (Bottom)

Past Research and Validation

Simple Rectangular Box Building

The modeling procedure was developed by Martin and was validated on a 1/3 scale model built and tested in a wind tunnel at the University of Florida by Datin (2009) (Figure 2a). The structure itself was relatively simple (Figure 2b) with only 2 sheathing types and no geometric irregularities.

The structural modeling method devised was validated for the following:

- 2D Individual Truss Behavior
- 3D Roof Assembly Behavior
- 2D Shear Wall Behavior
- 3D Influence Functions for the Entire Building

Martin explored load cases of uniform uplift, simulated hurricane uplift, and ASCE 7-05 Wind Pressures.

More Realistic L-Shaped Structure

Pfretzschner used and further developed the modeling techniques of Martin; this effort was to further the applicability of the method and validate load sharing and system behaviors in a more complex and realistic model (Figures 3a and 3b).

The validation procedure involved:

- 2D Truss Behavior
- 3D Roof Assembly Behavior
- 2D Shear Wall Behavior
- 3D L-Shaped House Behavior

Pfretzschner similarly investigated uniform uplift and wind loads developed using ASCE 7-05 Main Wind Force Resisting System procedures.

Modeling Approach

Structural

Modeling is accomplished using SAP2000, a finite-element software developed by Computer and Structures Inc., using built in frame, spring, and shell elements to appropriately capture the structural behavior of a light-frame modular building. Isotropic material properties were assumed for wood frame elements, such as wall studs. Whereas shell elements (wall and roof sheathing) were modeled using anisotropic properties and are either obtained from the National Design Specifications, Wood Handbook, or OSULaminates (a Java™ package developed by Dr. Nairn).

To simplify the complexity of connections, fixity and release conditions were assumed based on connection details for the given structure and are either regarded as pinned or rigid. Additionally, all non-structural elements, such as interior walls and bearing pads, were not included in the model.

Wind Loads

Wind loads were determined using Part 1 and 2 of the ASCE 7-10 Minimum Design Loads for Buildings and Other Structures "Envelope Method". This method produces positive and negative pressure values on each surface element so that the worst case loading scenario for individual structural elements as well as overall uplift can be explored.

Objective

The structure of interest in this study is a modular school classroom. In designing these buildings, several foundation configurations are explored to understand the effects on uplift forces in each of the foundation components.

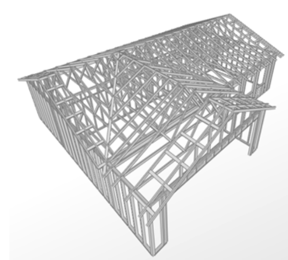


Figure 3a (Top) and Figure 3b (Bottom)

Practical Modeling Methods For Light-Frame Structures

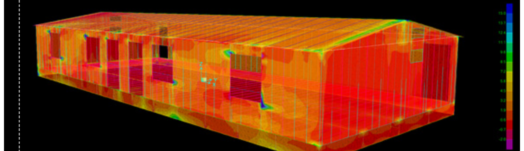


Figure 4

Light-Frame Modular Building

- 28'x64' Modular Classroom
- Mixed Douglas-Fir and Hem Fir
- T1-11 and OSB Sheathing
- Rafter Roof Design
- Inclusion of Subfloor

The structure modeled is a modular classroom that is widely used on the West Coast as temporary and more permanent buildings (Figures 1a and 1b). Due to the nature of modular buildings, the foundation design is dictated largely by local regulation. Because the structures must be designed for multiple foundation scenarios, the typical design of these structures requires that they "sit" on Concrete Masonry Units to spread gravity loads into the existing slab foundation. The only mechanism to resist wind uplift forces are steel ties which are evenly spaced and secured into the foundation.

A SAP2000 model was created using the techniques developed by Martin to accurately model system behavior and load paths caused by wind loads.

Shown in Figure 4 is a test load of constant shear (25 plf) across the ridge beam and the maximum principal stresses Tension (-) and Compression (+) between -2 to 15 psi to obtain a finer detail within the stress color contours near openings and stiffer connections. Though this model in Figure 4 is incomplete, stress concentrations can be seen near wall openings and stiffer double studs near the foundation where loads are eventually transferred.

Validation of wall element properties will be completed by testing full-scale walls in a static lateral load test. Several other physical testing methods are being considered to evaluate the stiffness of the wall panels.

Oregon State UNIVERSITY