Performance of Wood Roofs under Dynamic Wind Loads

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Recent experimental results have shown significant differences in critical structural responses when roofs are excited with actual wind load data, which is a time and spatially-varying dynamic load, rather than the uniform, static, code-based wind load model (Sinno and Taylor 1995; Fowler 2001). Moreover, refined analyses have demonstrated shortcomings in load distribution assumptions for simplified code-specified procedures (Kasal et al. 2004). As an expected result, preliminary investigations of wood roof reliability using the actual dynamic load data gives significantly different results than using the uniform, static load for analysis (Rocha, Eamon, and Sinno 2005). The concern is that different wood roof types, and even different panels on the same roof, are currently designed to varying levels of safety. Reliability studies have shown that a few sheathing panels govern the safety of the entire roof, if roof failure (by breaking of the house envelope and allowing penetration of wind-driven rain) is measured by panel failure anywhere on the roof (Rocha, Eamon, and Sinno 2005). In light of the enormous degree of economic damage that was recently caused by high-wind events, maintaining an adequate level of roof safety for future construction is critical.

Research Objective

The objective of this study is to investigate the performance of wood roofs using actual dynamic wind loads. The goal is to identify deficiencies in current design recommendations, and ultimately to suggest new design guidelines that may provide an adequate and more uniform level of roof sheathing reliability.

Scope

There are two phases to the research. The first phase will focus on developing methodology, computational tools, and results for a single, typical wood roof, for which experimental data is readily available. The second phase expands the research to consider various common wood roof parameters.

Phase I Research Tasks

1. Gather Experimental Data.
   A fully-instrumented FPL study house off the coast of Florida has collected roof panel wind load pressure data as well as roof member reaction data during hurricane Katrina. This information will be used in the first phase of this study.

2. Construct Finite Element (FE) Model of Roof
   An FE model of the roof can be constructed and loaded with the wind load data gathered in task 1. This behavior can be compared to the recorded experimental response for model verification and calibration. The model is needed for step 3.

3. Reliability Analysis
   The relevant roof pressure wind load statistics can be estimated from the data gathered in step 1. Resistance statistics exist on wood sheathing panel fasteners (nails) as well as overall panel resistance. A structural reliability model of the roof panels as well as roof system can be developed; the structural response is to be evaluated with the FE models developed in step 2. The reliability of the roof panels can be computed. Discrepancies in panel reliabilities can be identified.

Phase II Research Tasks

1. Gather Experimental Data.
   Collected from wind tunnel studies, a large database of wind loads exists. However, it is not certain that sufficient information is available that describes the time and spatial distribution of pressure across the roof surface for a variety of typical roof configurations. In addition, a sufficient number of wind load sample profiles is necessary for the same roof type to develop the statistical parameters for the loads. Wind pressure data that is not available can be determined experimentally in a boundary layer wind tunnel tests.

   Wind data is needed that considers a variety of roof and load parameters:

   - roof slope
   - roof overhangs
   - wind incident angles
   - roof type (gable, hipped, sloped).
   - building height
   - building size
   - wind speed
   - topography/exposure

   Not all combinations need be considered, as data can be more efficiently simulated in task 2.

2. Construct computational fluid dynamics models (CFD)
   A CFD model of the local wind pressures can be constructed. Experimental data gathered from task 1 can be used for model verification. The load pressures for many different (but similar) roof and load parameters can be developed by simulation, avoiding the need for a large number of relatively costly wind tunnel tests.

3. Conduct experimental tests for structural response
   Full-scale models of a variety of roof types can be constructed and tested for structural response. Here the actual time and spatially-varying dynamic wind load data developed from tasks #1 and #2 can be used to load the structural specimens real-time in MSU's Wind Research Laboratory. Fastener reactions, roof deflections, strains, and panel failures can be recorded. This information can be compared to the roof behavior found from loading using the code-specified uniform, static load model.

4. Construct Finite Element (FE) Model of Roofs
   FE models of the roofs can be constructed and loaded with the data gathered in tasks 1 & 2. This behavior can be compared to the experimental results of task 3 for model verification and calibration. The FE models are needed for step 5.

5. Reliability Analysis
   The relevant roof pressure wind load statistics can be developed from the data gathered in step 1. Resistance statistics exist on wood sheathing panel fasteners (nails) as well as overall panel

resistance. A structural reliability model of the roof panels as well as roof system can be developed; the structural response is to be evaluated with the FE models developed in step 4. The reliability of the roof panels can be computed.

Research Results

Research has shown that the principal economic damage from a high-wind event occurs due to component failure of the roof envelope and resulting penetration of wind-driven rain (Soltis 1984; Sparks et al. 1994). Thus the failure of a single roof panel governs the reliability of the entire roof. Therefore, there is a desire to minimize variations in sheathing panel reliability on a particular roof as well as different roof types, and to ensure that all panels have an adequate level of reliability. New design guidelines, which may involve modifying nailing schedules or panel strengths, will be recommended to insure an adequate and consistent level of wood roof reliability.

Phase I Budget
Period of Performance: May 15-Aug 15 2006

Eamon: 75% effort	15895
overhead: 43%	6835
fringe: 30%	4769
Computational expenses	500
Total:	$27,999