Overview

• Why do it?

• Case Study: the DuraKit Shelter

• Grand Plan for a Full-scale Facility
Wind Damage – Hurricane Iniki
Why Do It?

• “understand how load paths develop and are maintained up to failure”
  – Dr. Michael Gaus, AAWE

• demonstrate satisfactory performance of complex systems to regulatory authorities

• educate builders, owners about construction quality
Case Study: the DuraKit Shelter

DuraKit Facility, Bond Head Ontario
A Corrugated Fibreboard House

Dimensions:
- Width: 6.1m (20ft)
- Depth: 3.4m (11ft)
- Front Depth: 4.9m (16ft)
What we know about cardboard

- Box Engineering

Stack of boxes containing DVD players

Compression in walls at bottom of stack
Loading of Shelter Roof

Wind

Shear

Moment
Initial Roof Design
Roof Redesign

Original

Splice

Response (Snow Load)

Tearing

Revised
Testing at UWO Structures Lab: it works!
Wind Loading Criteria

hurricane-force winds, approximate wind speed 36m/s (130km/h)
Finite Element Analysis of Shelter

By El Damatty

Key: Blue = good, Green = fair, Orange = trouble
Effect of Window Openings

No Openings

End Window and Door Openings
Roof Loading System

applied load
(water barrel)
2kN

whiffle
tree

10kN
(shelter)
Interior Whiffle Tree

Distributes Loads Horizontally and Vertically
Envelope Failure

Before

After
Failure
Waisted Rod for Load Measurement
Analysis of Response

Effect of Overturning Moment on Vertical Reactions

- Load (kN)
- Total wall load (kN)

(shelter)
Results

• **Components:**
  - Walls: 2.8 kPa (60 psf)
  - Roof: 3.9 kPa uplift (81 psf)

• **Full Scale Shelter:**
  - Walls: 2.3 kPa (47 psf)
  - Roof: 2.5/2.2 kPa uplift (53/45 psf)

• Sensitive to:
  - through-thickness tension
  - construction flaws
Impact of Full-scale Tests

• Captured system behaviour and sensitivity to connection details missed by component tests
• Captured quality of construction missed by finite element analysis
• Demonstrated failure load
• Educated all (builders, owners, researchers) involved
Application to Wood Houses

• Light-frame systems:
  – poor load path
  – little engineering
  – hard to define structural components

• Objective-based codes coming

• Reverse engineering necessary to achieve optimization
  – take out what is overdesigned
  – put back what is underdesigned
Downburst Winds

Shown by Savory, original Waranauskas

- 2/40 experienced in Canada
- 2/10 experienced in US/Australia
Wind Tunnel Testing

Tests by Galsworthy & McKinnon
Construction Quality

Wind Loads on Houses

Wind Tunnel Tests + LRC Analysis

Downburst Simulator

Structural Analysis for Load Paths

Instrumentation (Smith NSERC)

Full-scale Validation in Test Facility

Construction Quality

Structural Analysis for Load Paths

Wind Loads on Houses

Downburst Simulator

Wind Tunnel Tests + LRC Analysis

Instrumentation (Smith NSERC)

Full-scale Validation in Test Facility
Full-scale facility: section

Typical Cross Section 01 Dec 2002
Preliminary Specifications

• Load cells for measuring internal loads and reactions
• Peak load capacity: 12 kPa/250 psf push/pull
• Spatial and temporal variation of loading
• Potential for cyclic testing
Fringe Benefits

• Quantification of water damage due to loss of sheathing in storms

• Building envelope durability
  – predict/mitigate rain load
  – HAM benchmarking

• Wind-induced internal pressures

• Test proprietary retrofit devices
Implementation of Results

• Changes to building codes
• Fortified home programs
• Hands-on educational facility for
  – community college students
  – graduate students
  – builders, owners
• Enhanced apparatus, techniques and instrumentation for condemned housing