Testing Full-scale Houses to Simulated Extreme Wind Loads

Mike Bartlett

Institute for Catastrophic Loss Reduction

University of Western Ontario

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**

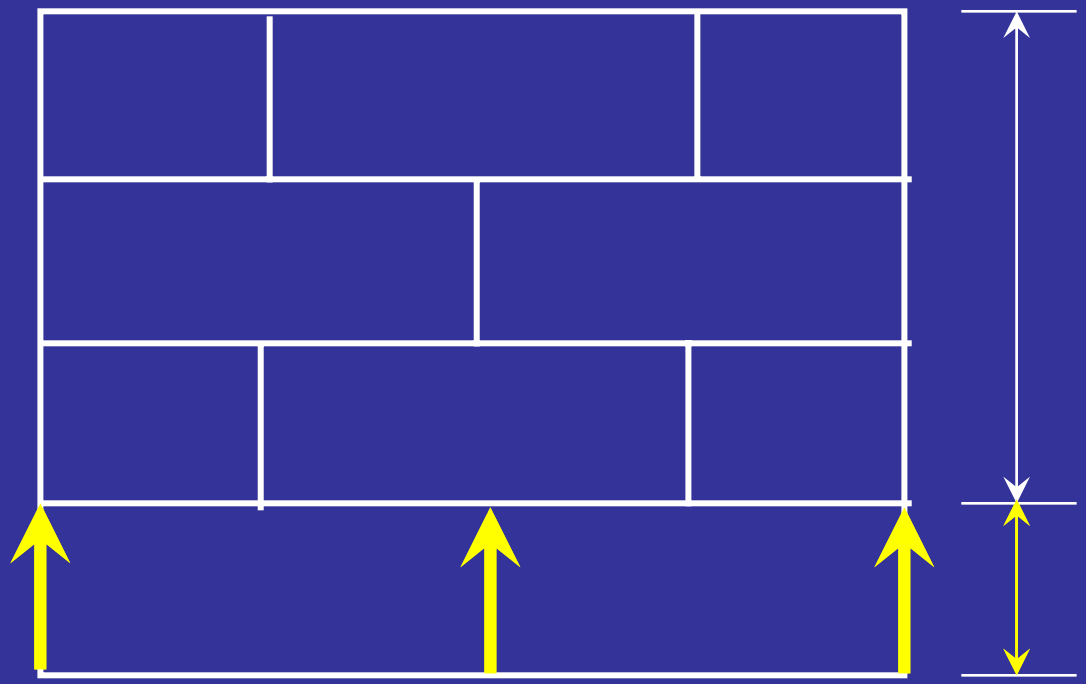
Case Study: the DuraKit Shelter

DuraKit Facility, Bond Head Ontario

A Corrugated Fibreboard House

What we know about cardboard

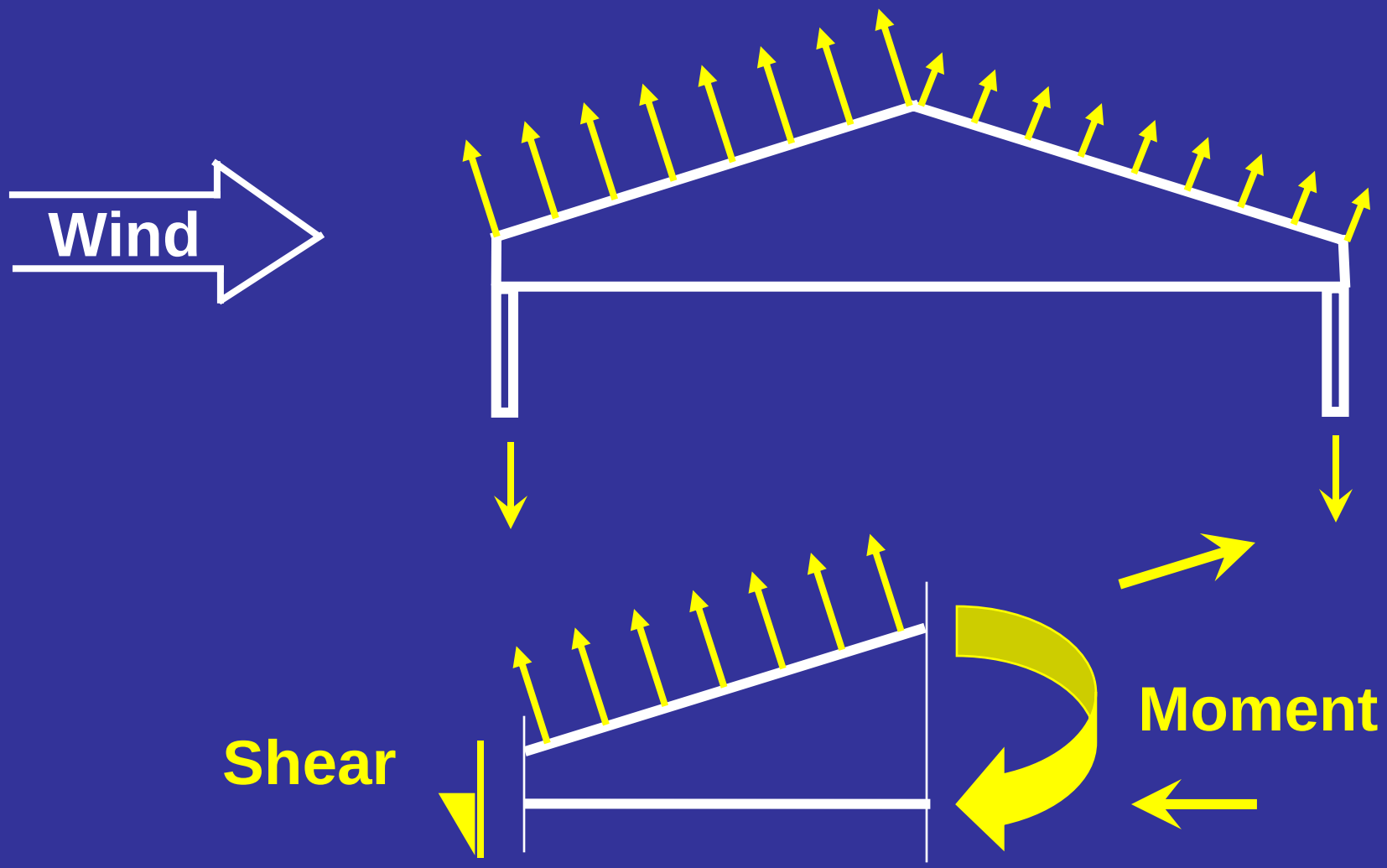
- **Box Engineering**



Stack of boxes containing DVD players

Compression in walls at bottom of stack

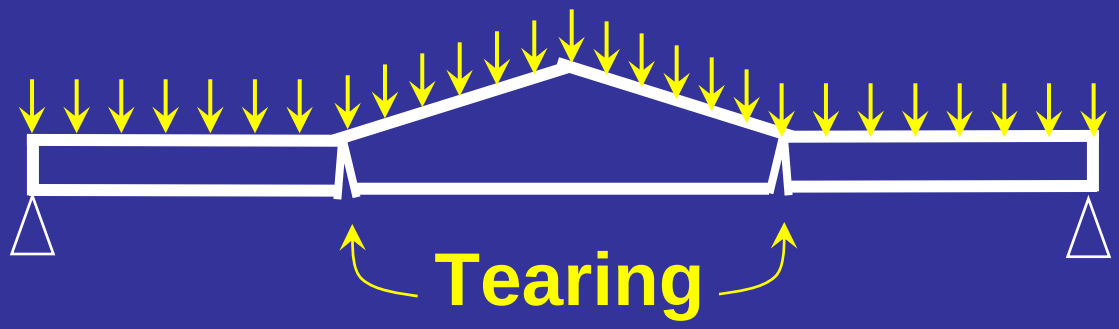
Loading of Shelter Roof



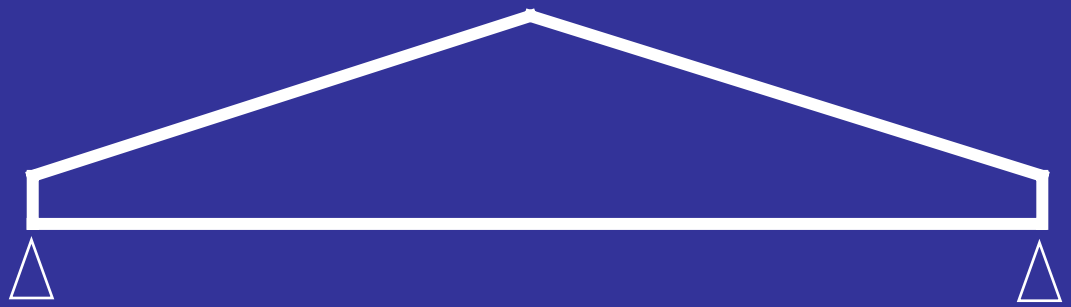

Initial Roof
Design

Roof Redesign

Original



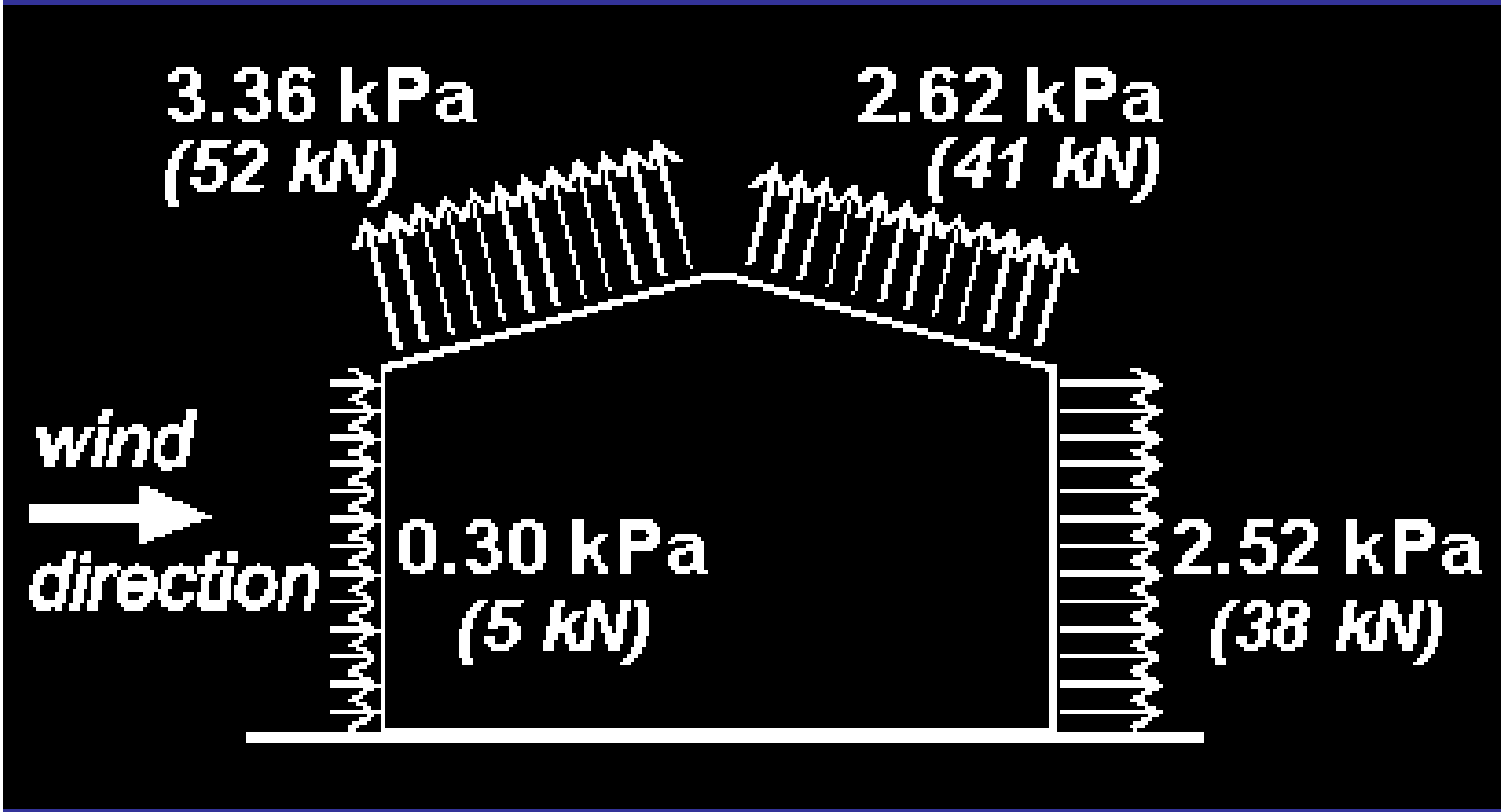
Response
(Snow Load)



Revised

Testing at UWO Structures Lab: it works!

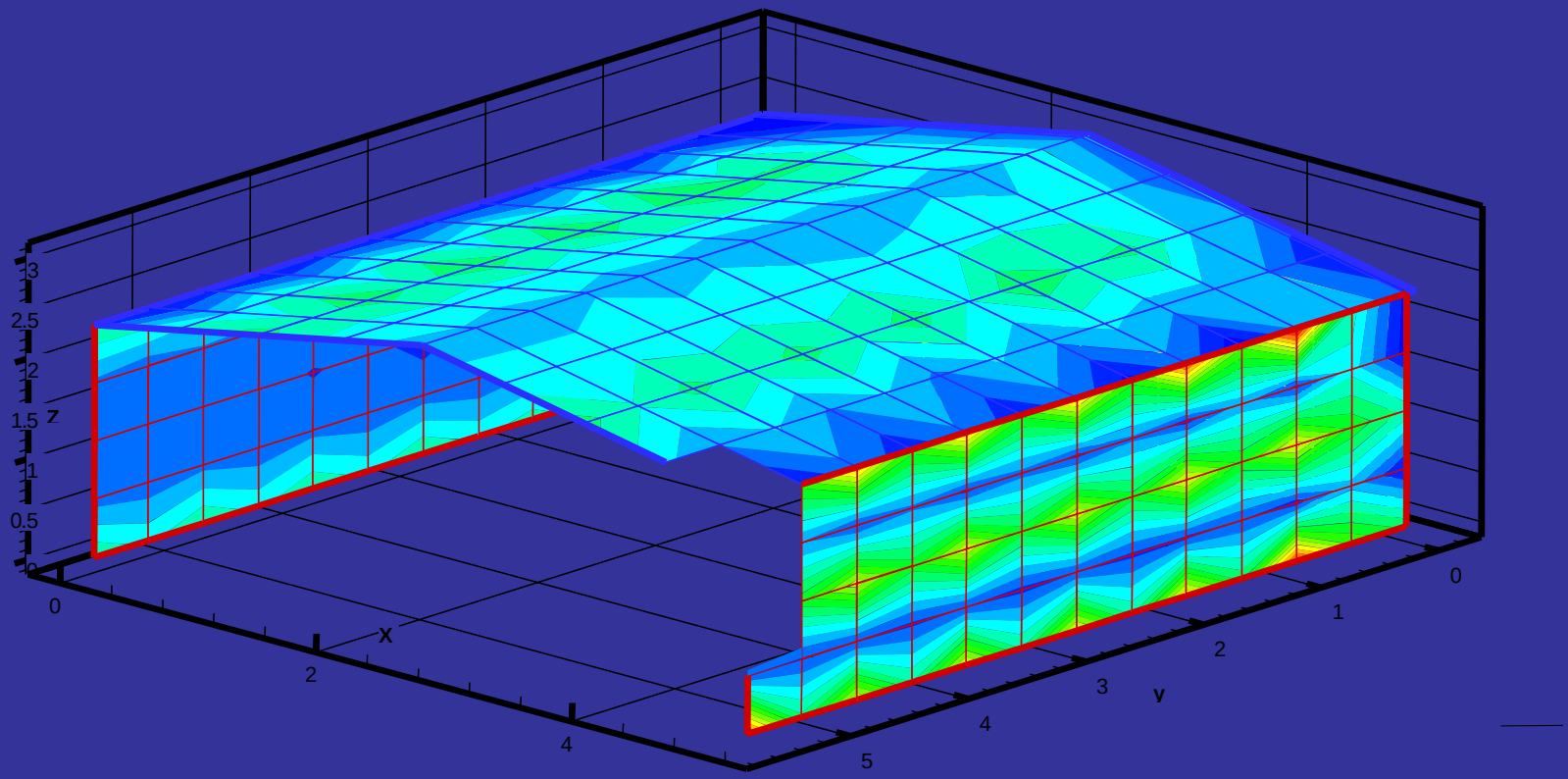
Wind Loading Criteria



hurricane-force winds,
approximate wind speed 36m/s (130km/h)

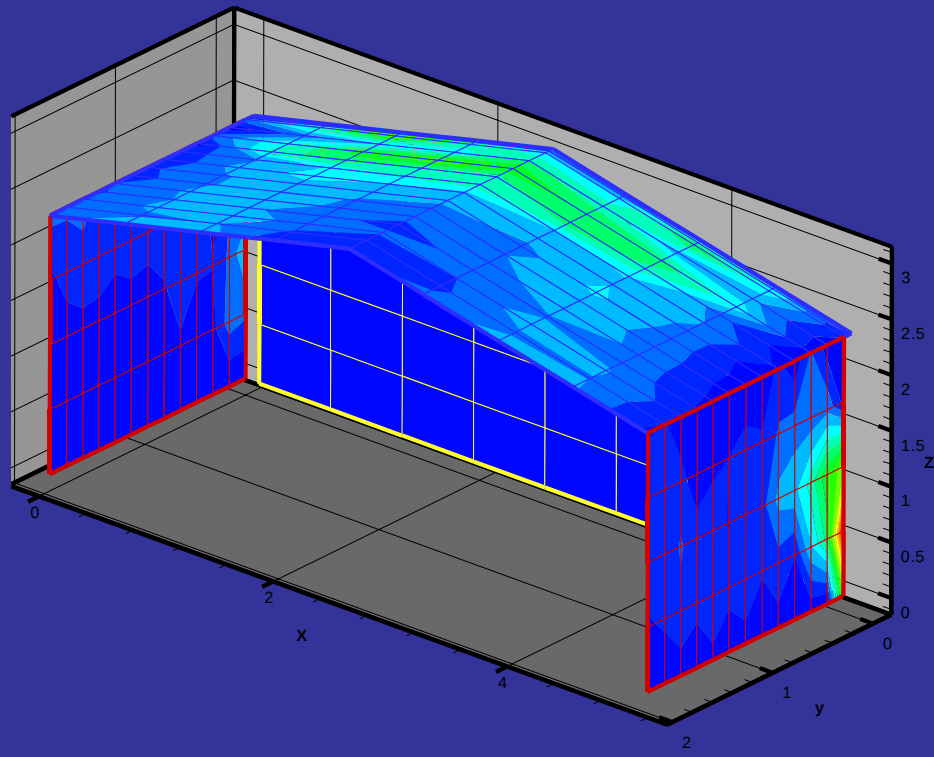
Finite Element Analysis of Shelter

By El Damatty

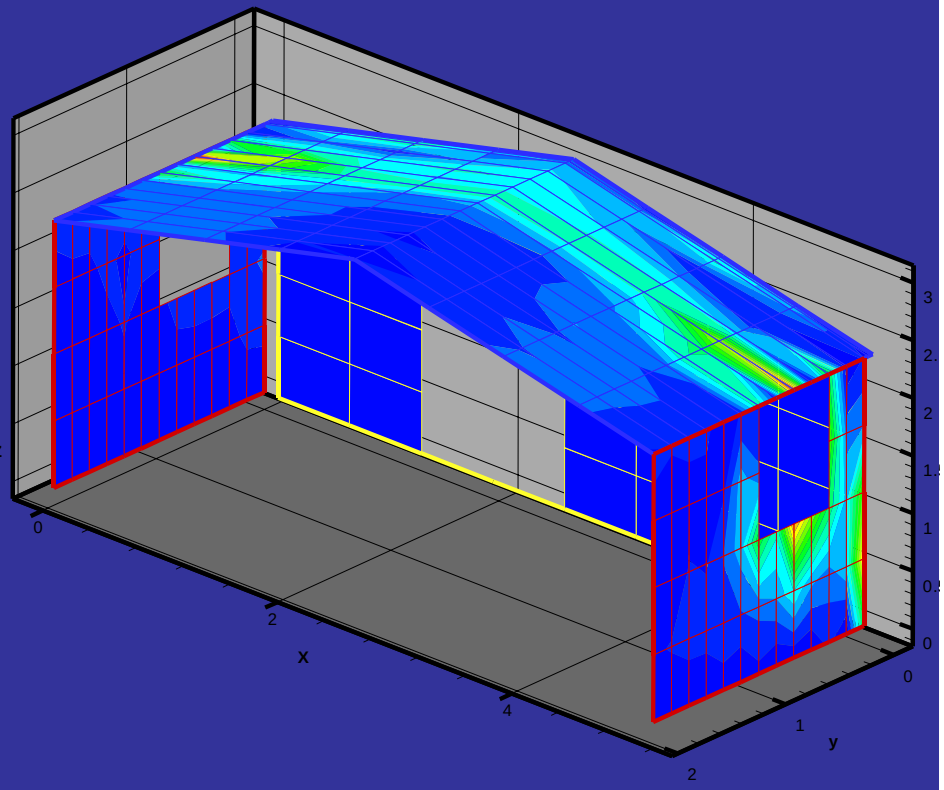


Key: Blue = good, Green = fair, Orange = trouble

Effect of Window Openings

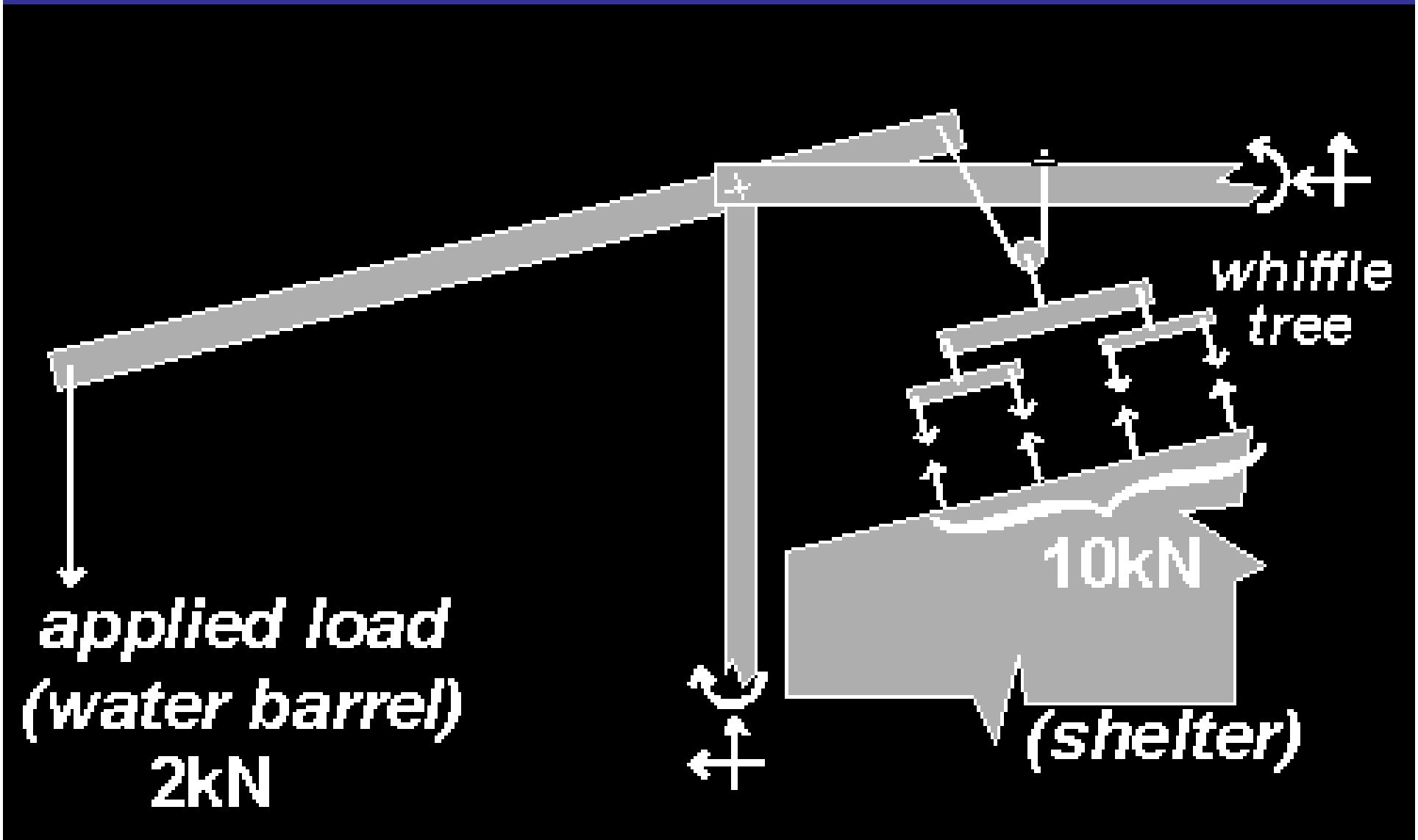


No Openings



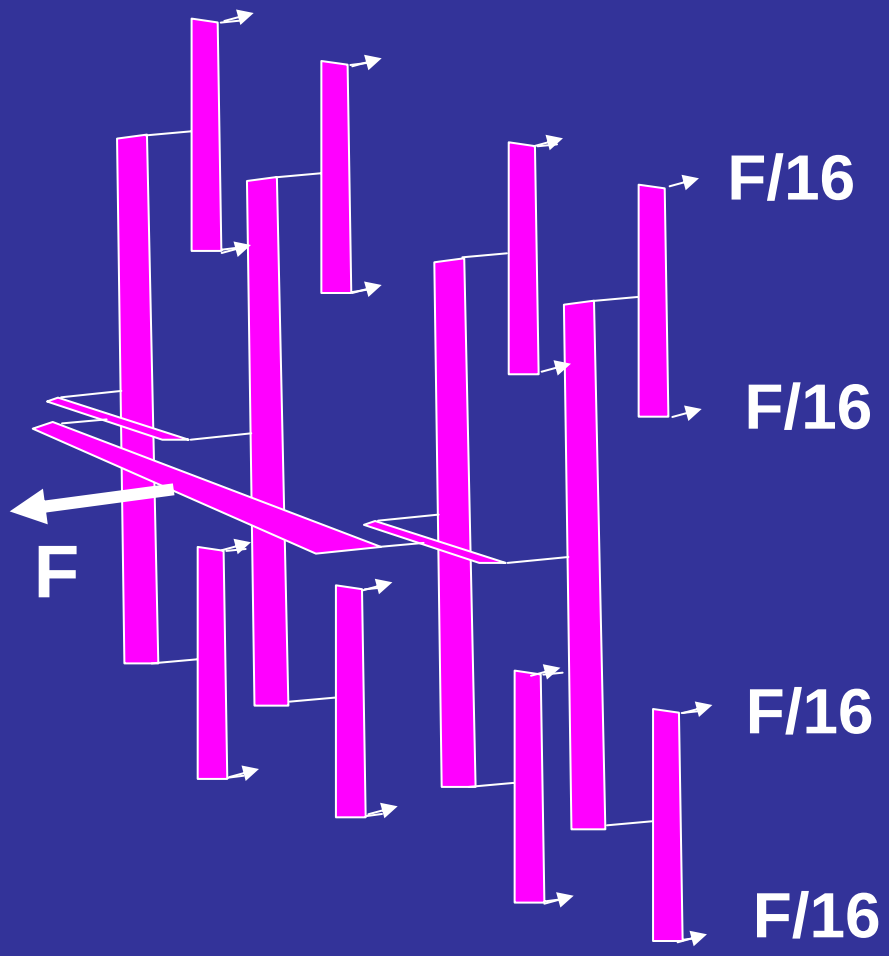
End Window and Door Openings

Roof Loading System

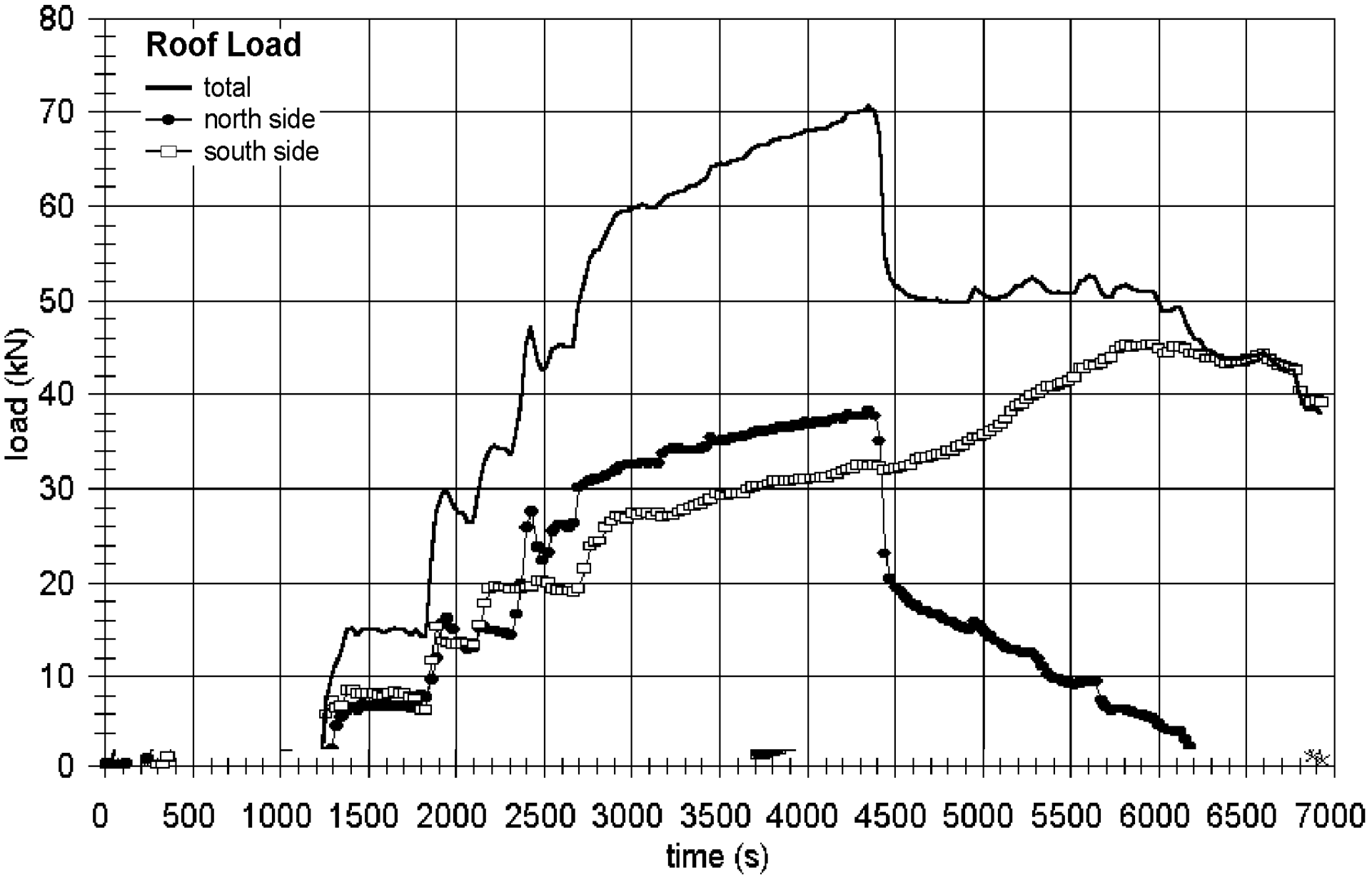


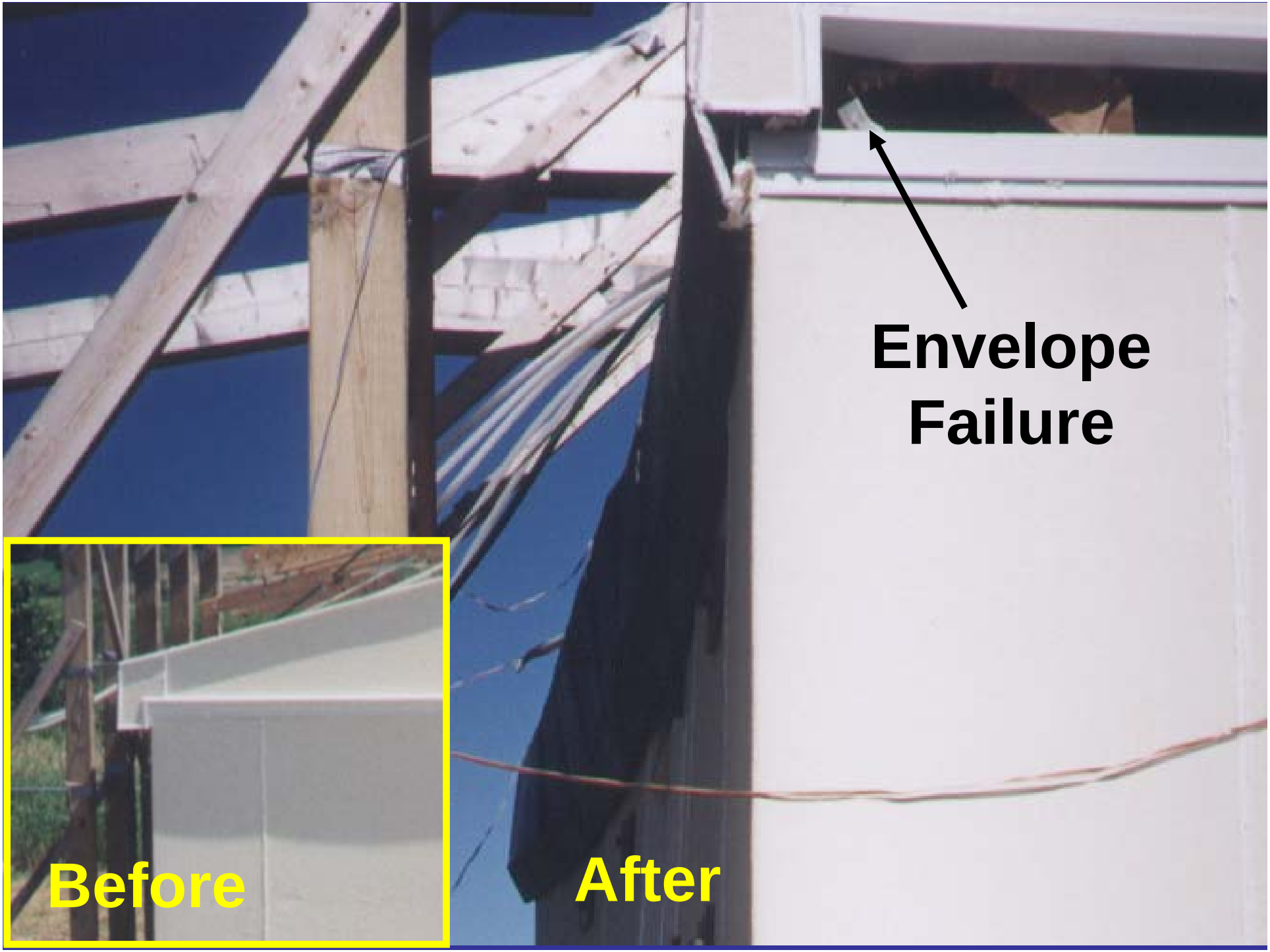
Interior Whiffle Tree

Distributes Loads Horizontally and Vertically

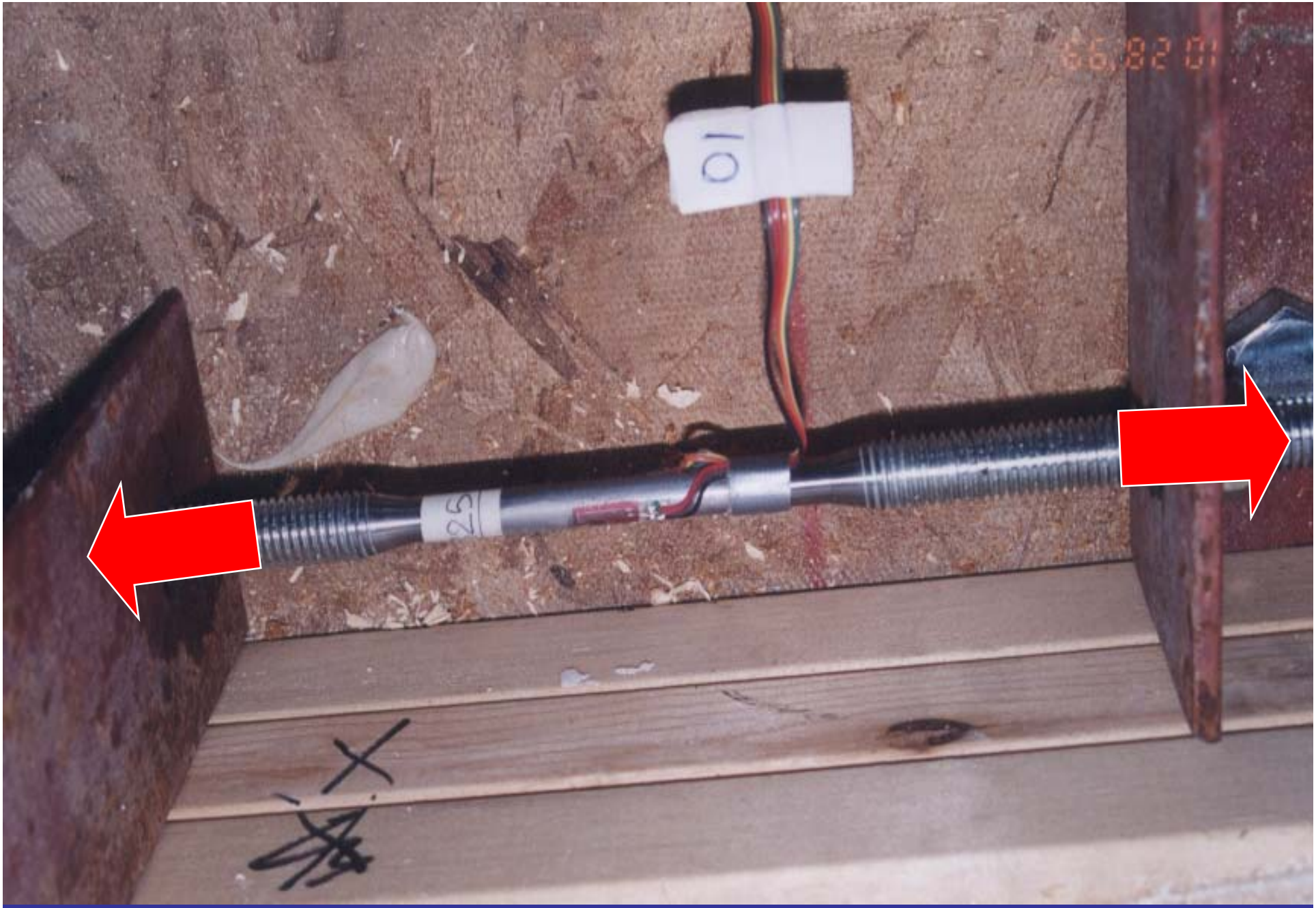


Load History



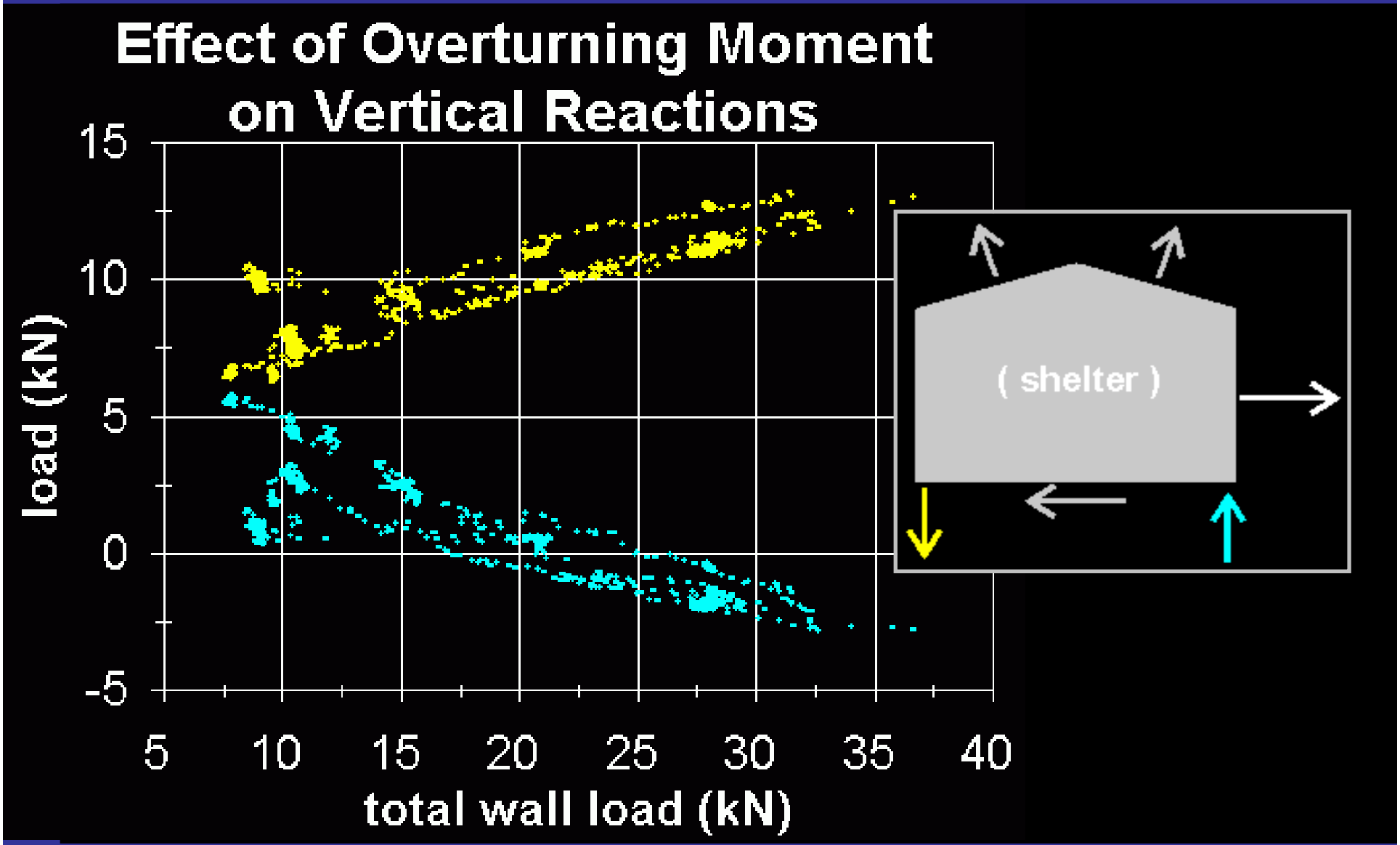

Envelope
Failure
Before
After


Failure



Waisted Rod for Load Measurement

Analysis of Response



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

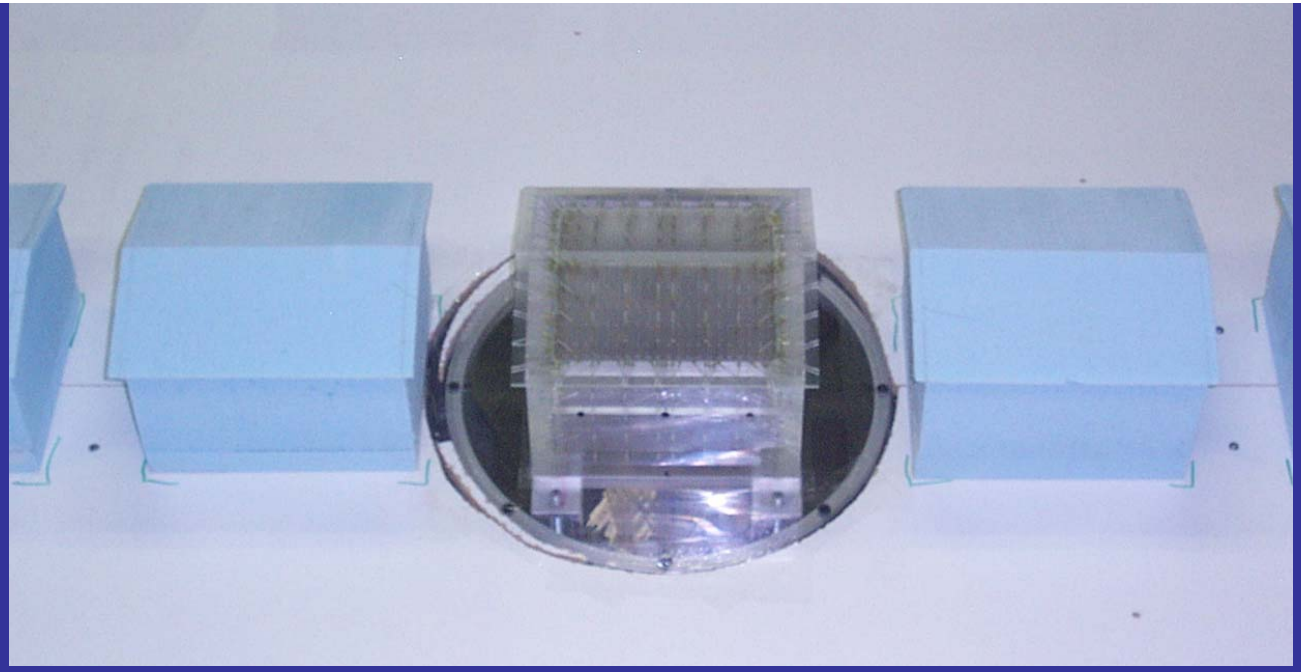
- Light-frame systems:
  - poor load path
  - little engineering
  - hard to define structural components
- Objective-based codes coming
- Reverse engineering necessary to achieve optimization
  - take out what is overdesigned
  - put back what is underdesigned

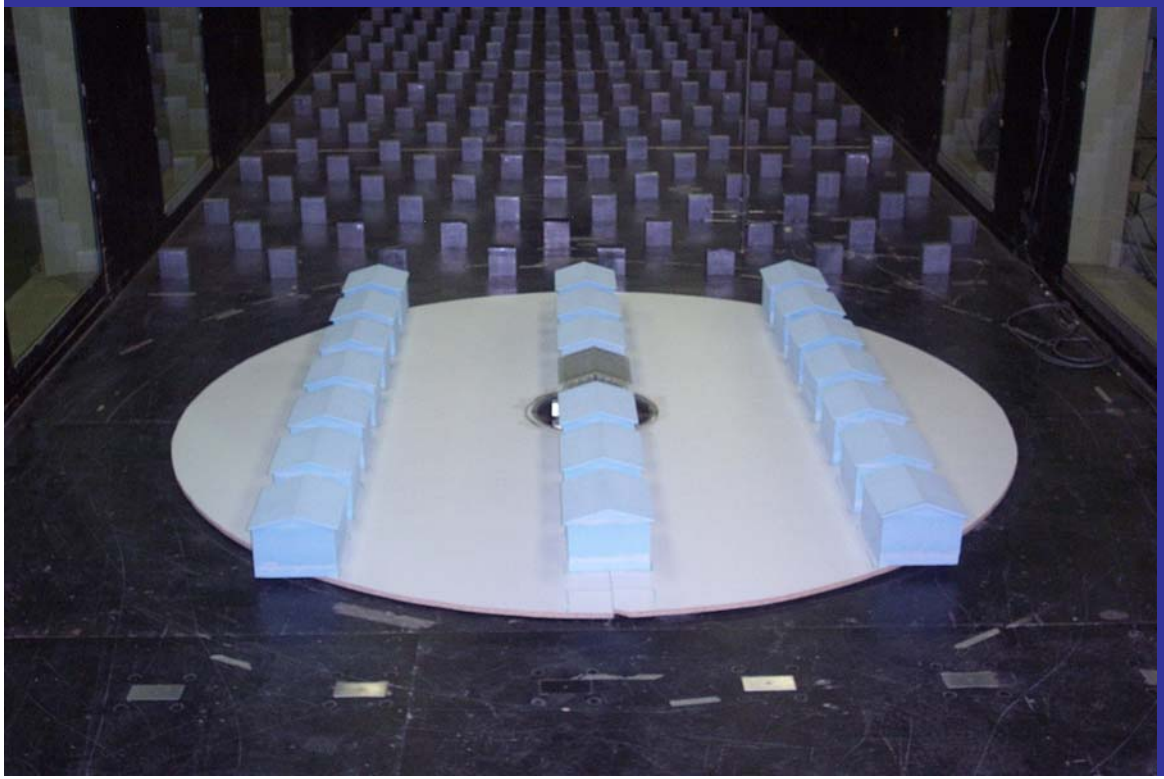
Downburst Winds

Shown by Savory, original Waranauskas

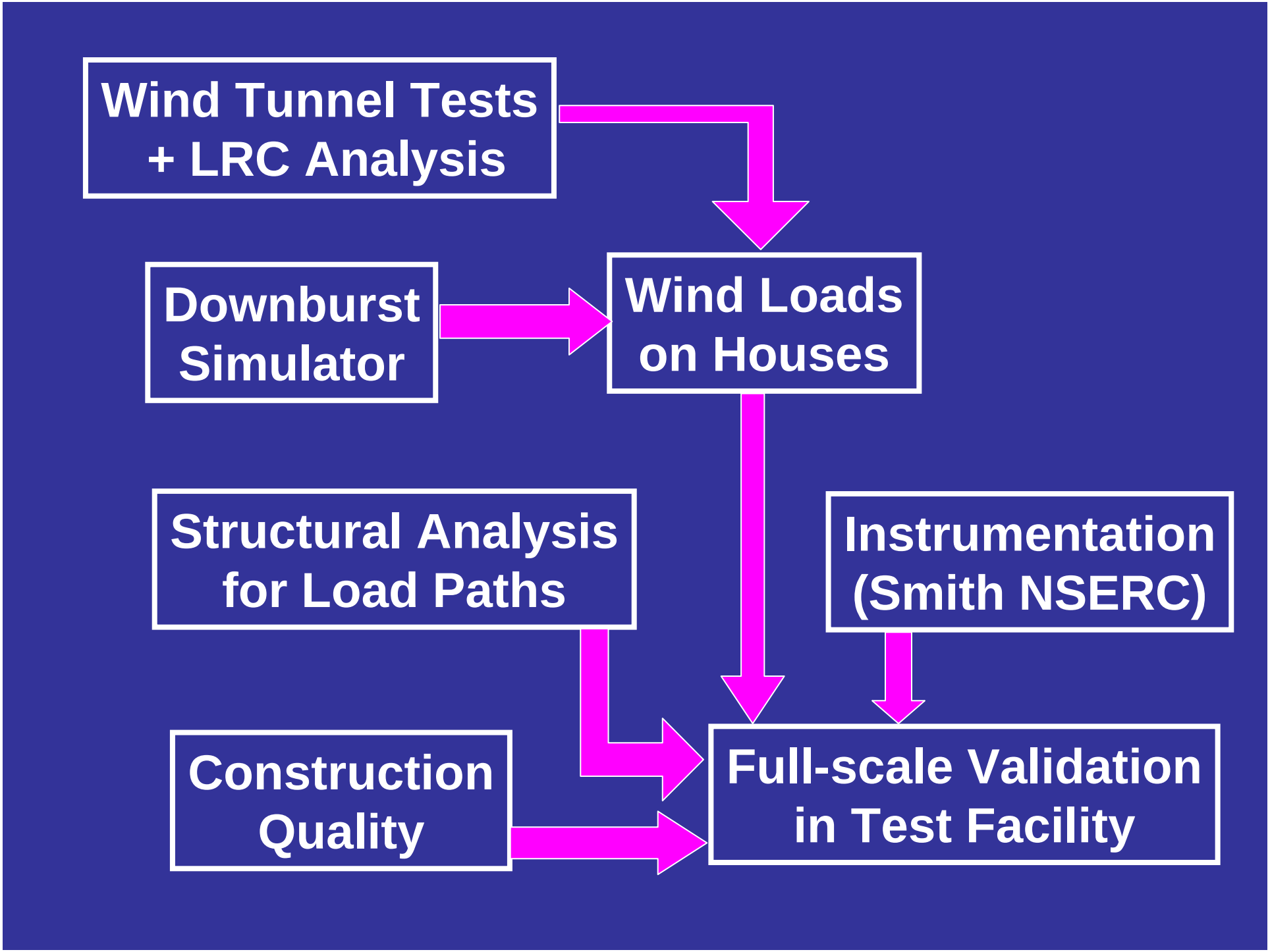
- 2/40 experienced in Canada
- 2/10 experienced in US/Australia

Wind Tunnel Testing

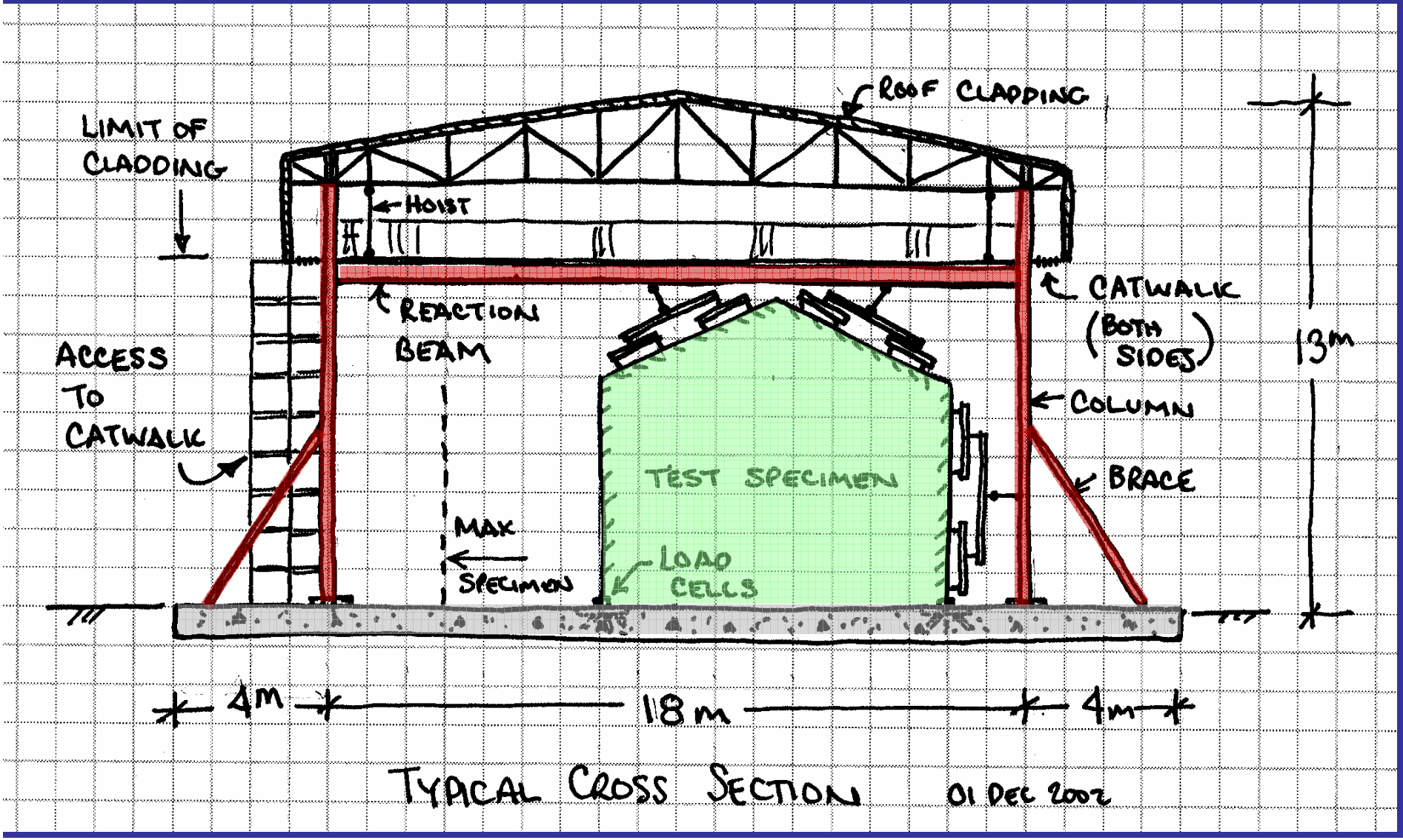




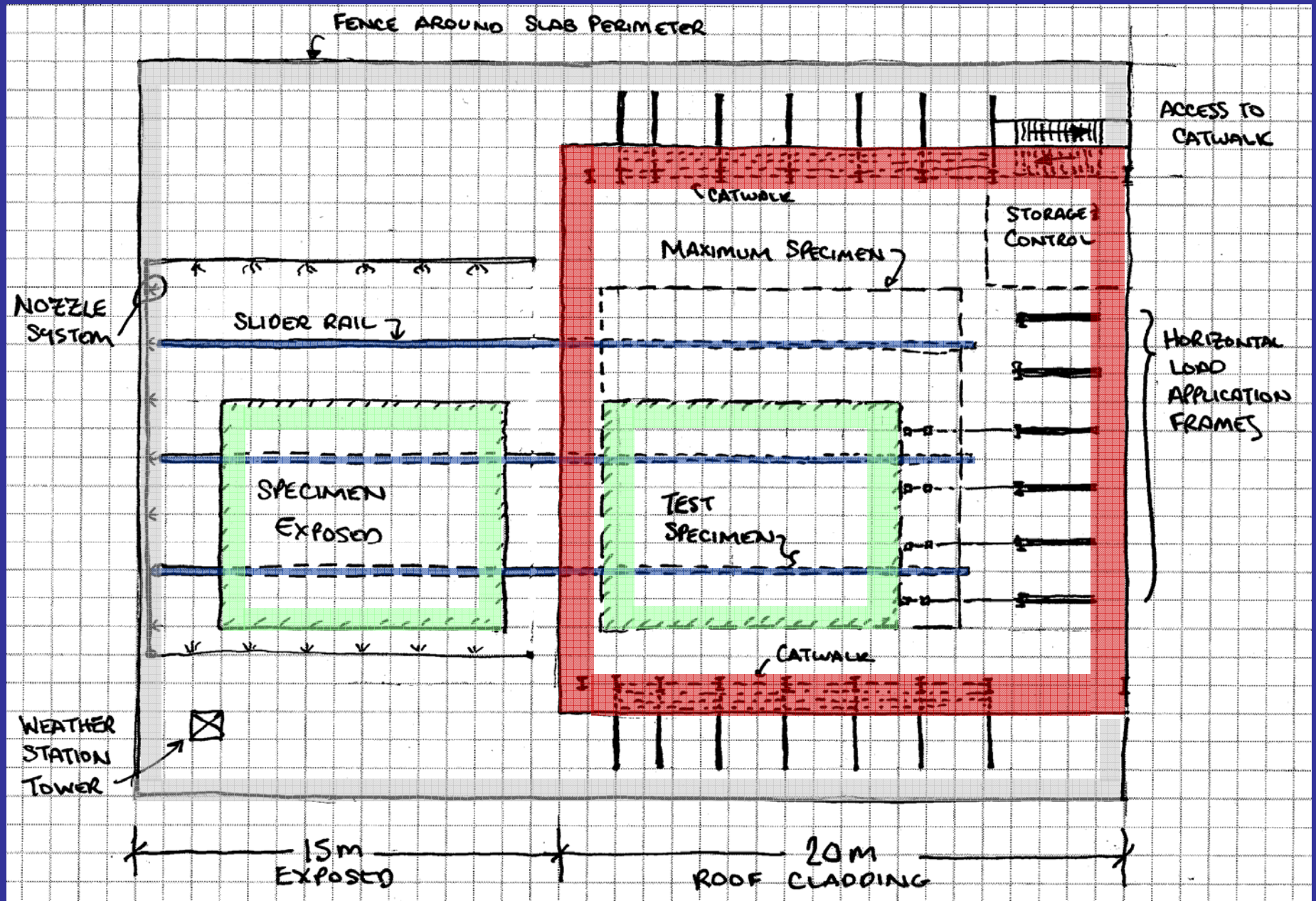
Tests by Galsworthy & McKinnon


Wind Tunnel Tests + LRC Analysis
Downburst Simulator
Wind Loads on Houses
Structural Analysis for Load Paths
Instrumentation (Smith NSERC)
Construction Quality
Full-scale Validation in Test Facility

Full-scale facility: section



Full-scale facility: plan



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