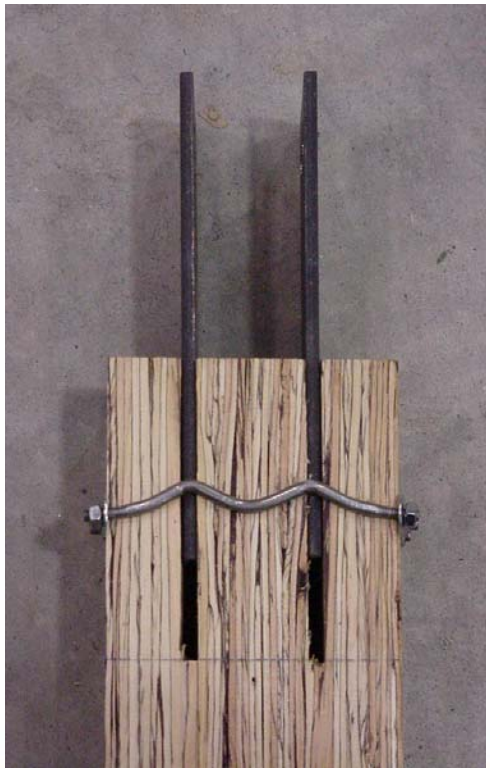
Comparison of Slender Dowel-Type Fasteners for Slotted-in Steel Plate Connections under Monotonic and Cyclic Loading



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Overview

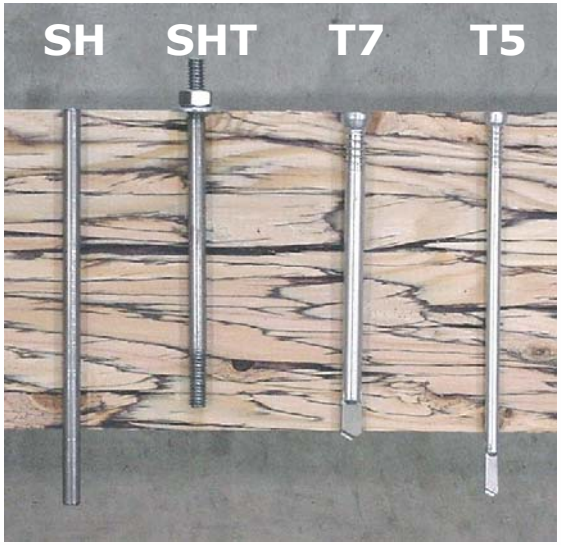
- **Objectives for Study**
- **Connection Types**
- **Experiments**
  - Test Setup
  - Results
- **Analysis**
  - Finite Element Model
  - Calibration
  - Results
- **Summary and Conclusions**

Objectives

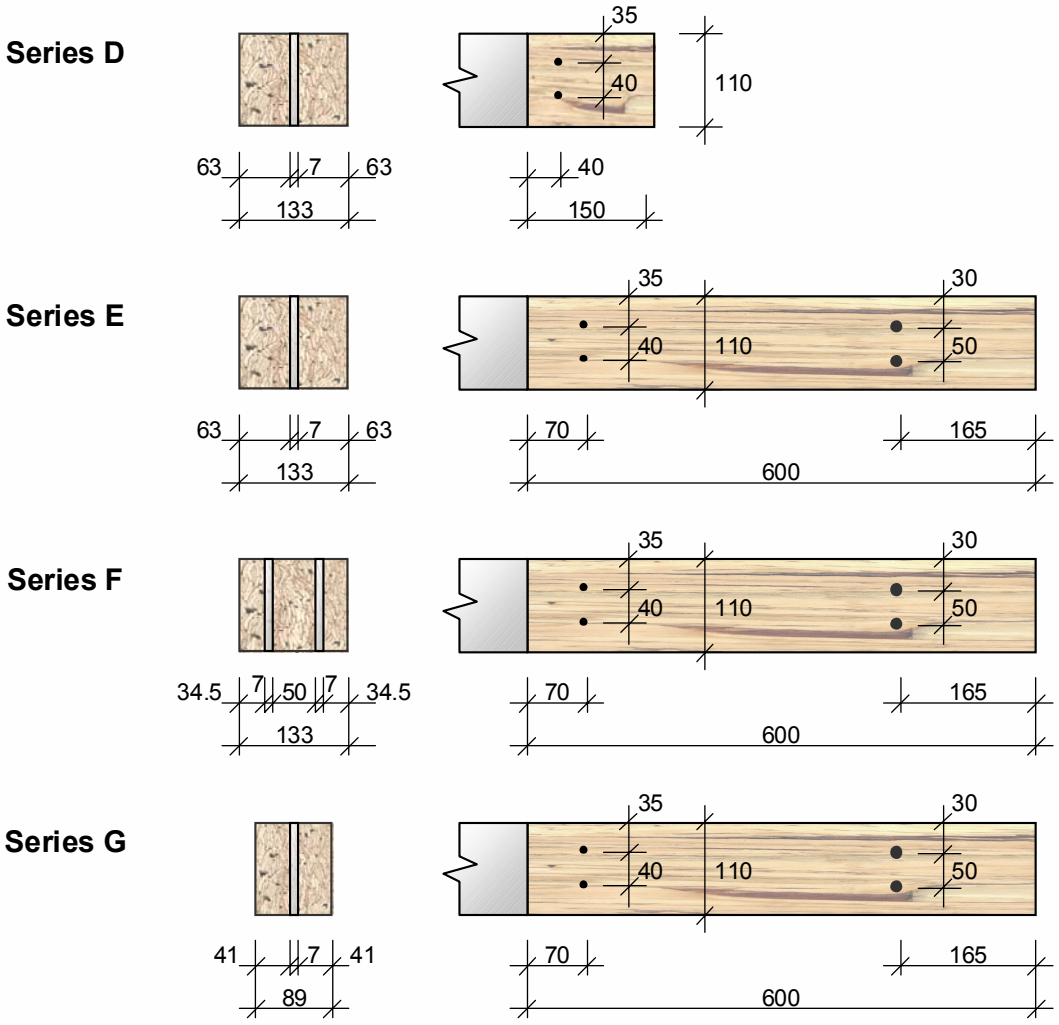
- Study influence of fastener head geometry on behaviour of ductile wood-steel-wood connections
- Compare self-drilling fastener (SFS WS) to traditional dowel / bolt
- Predict monotonic and cyclic behaviour using a finite element model
- Include into model:
  - Head restraint
  - Hole tolerances
  - Fastener material fatigue

Connection Types

- **4 Fastener Types:**

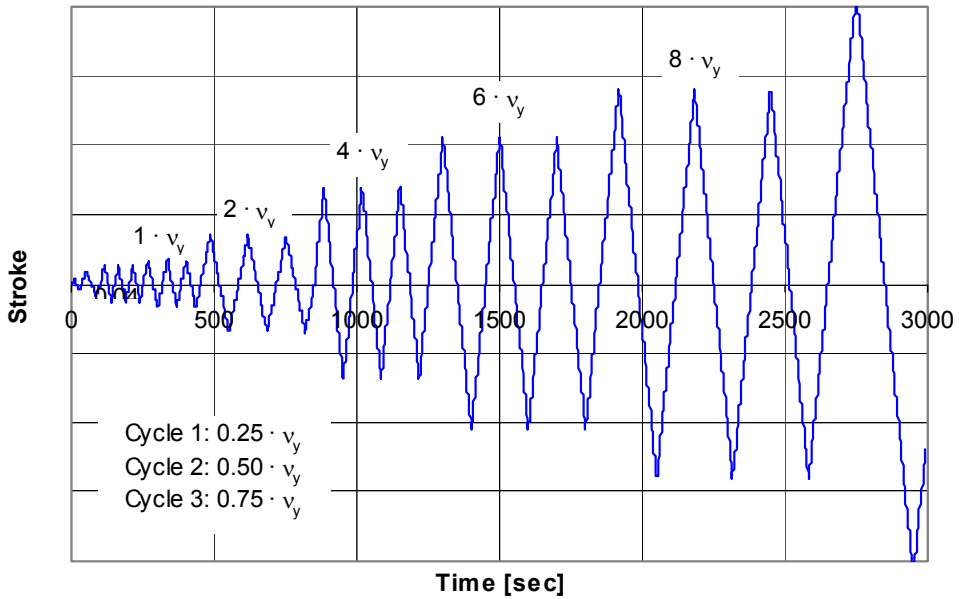


- **73 Tests** (D, E, F, G)
- 5 / 2 Replications



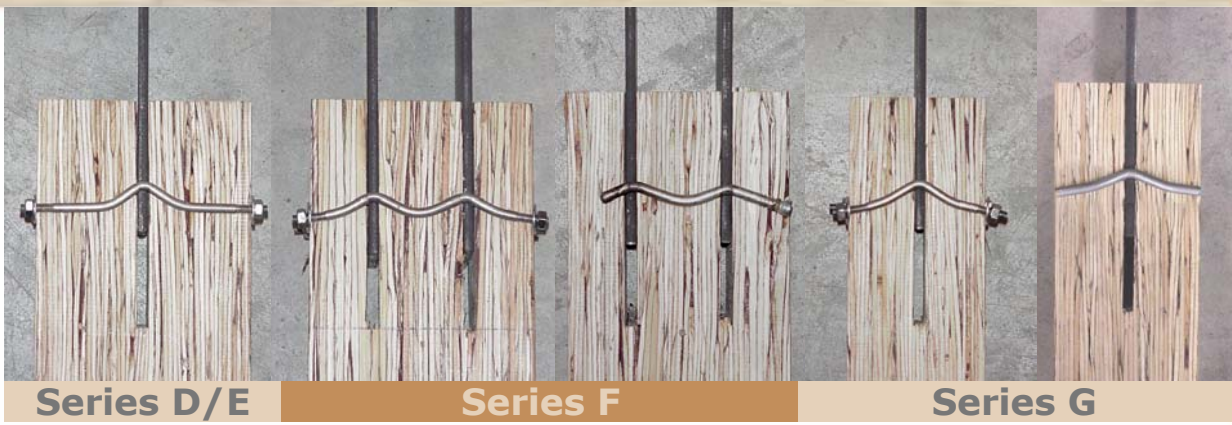
Experiments – Setup

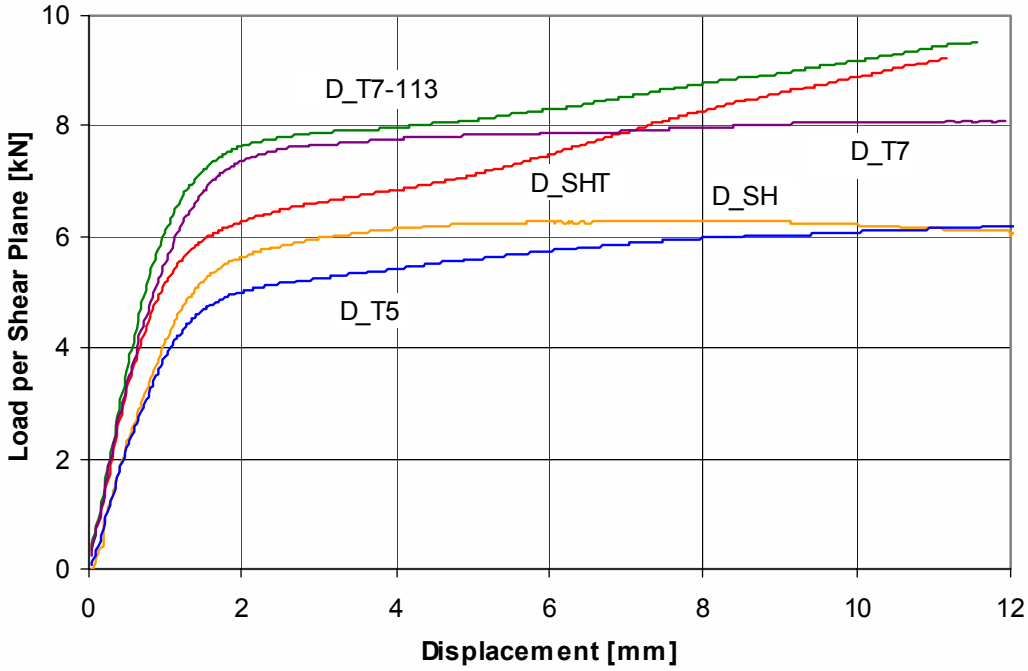
- **Monotonic: Ramp**
- **Cyclic: CEN Protocol**
  - Yield Point Based
  - 3 Cycles per Step
  - Low Speed



Experiments – Monotonic Results

- **Ductile Failure:**
  - Mode II / III
- **Limited Wood Failure:**
  - E / F / G
  - Tension Only
- **Head Influences:**
  - Strength
  - SHT > T7-XXX
  - Resists Spreading
- **Series F:**
  - Load Increase

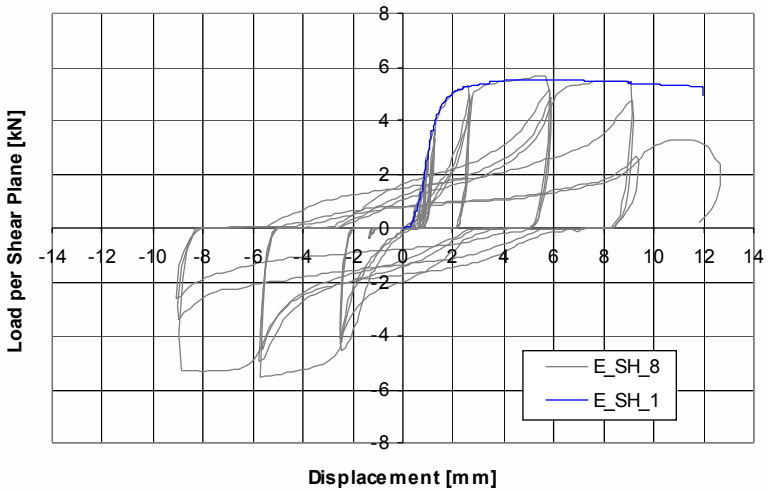


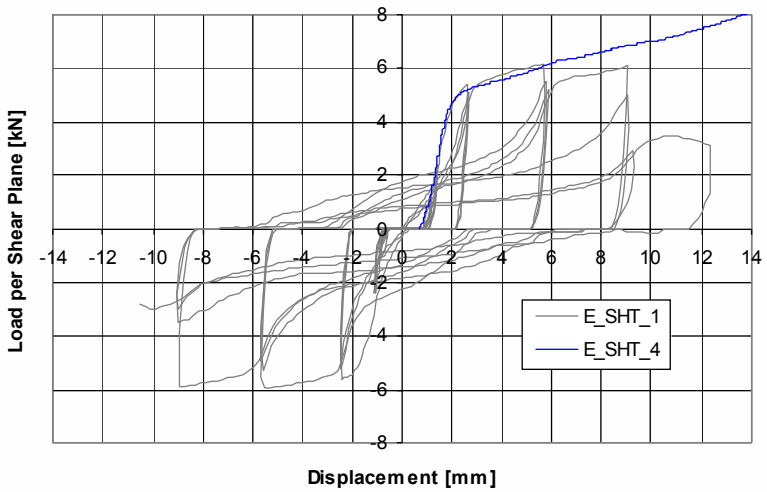


Experiments – Cyclic Results

- **Fatigue Failure**
  8-10 mm Displacement
- **No Ext. Wood Failure**
- **Fastener Permanent Elongation**
  → SHT Head Push-Out
- **Connection Slack Influence**

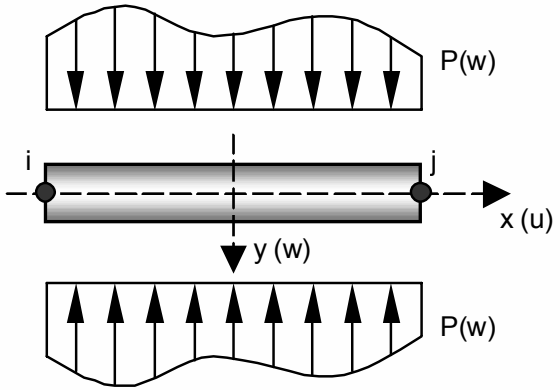
Series F (Composite Image)



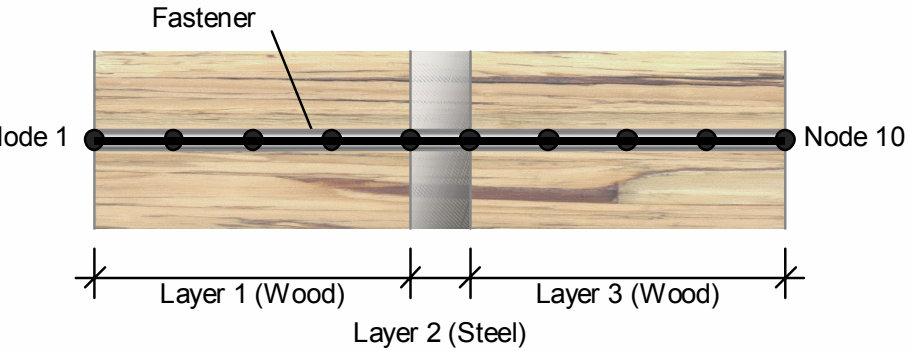


Analysis – Finite Element Model

- **Original Model (Foschi):**
  - 1D Elasto-plastic Beam on Nonlinear Foundation
    - Layer Properties
    - Gaps



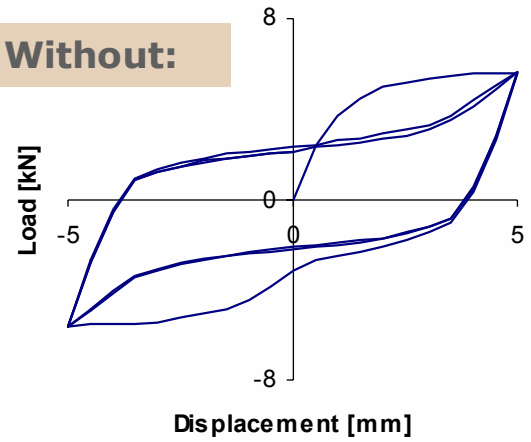
- **Modifications:**
  - Hole Tolerances
  - Fastener Head
  - Fastener Material Fatigue
  - Re-write / User Friendly



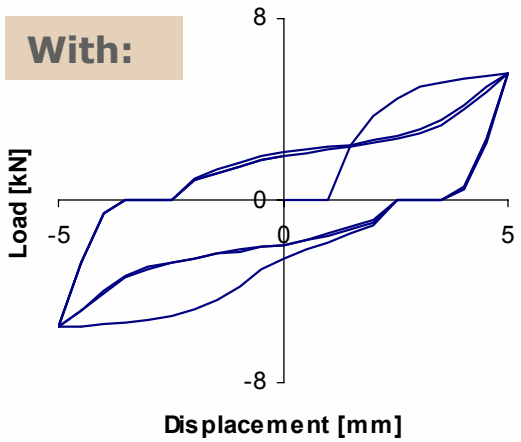
Analysis – Model Modifications

- **Hole Tolerances:**
  - Initial Gap

Without:

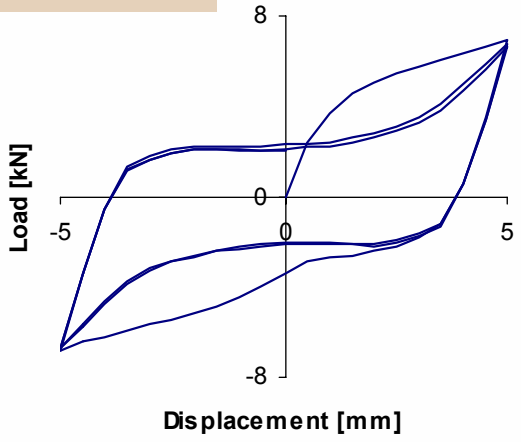


With:

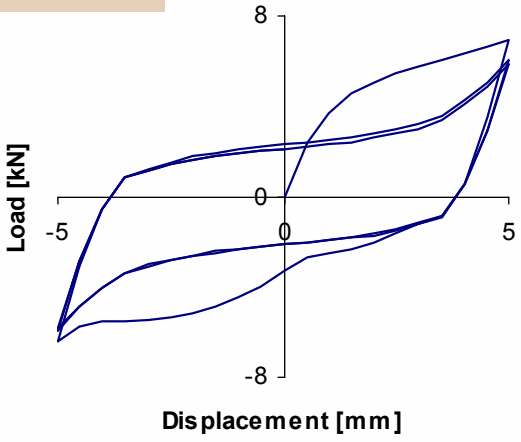


- **Fastener Head:**
  - Unidirectional Spring

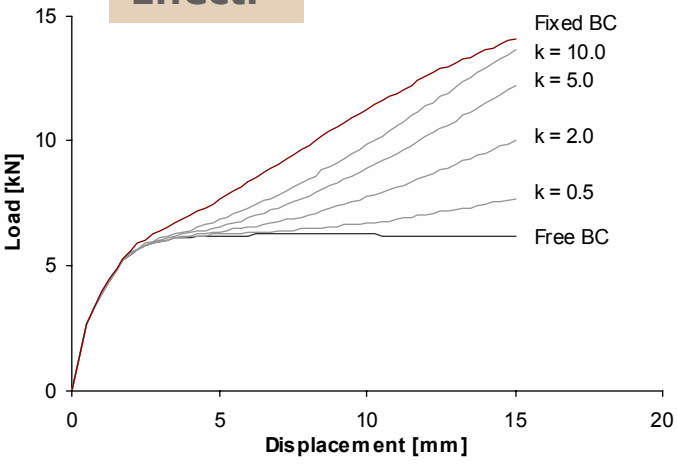
Without:



With:

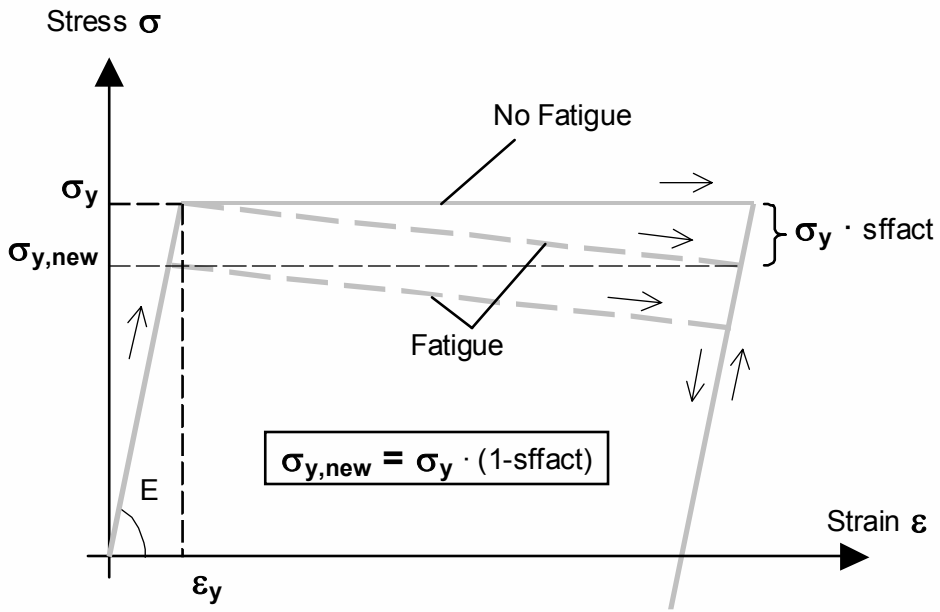


Effect:



Analysis – Model Modifications

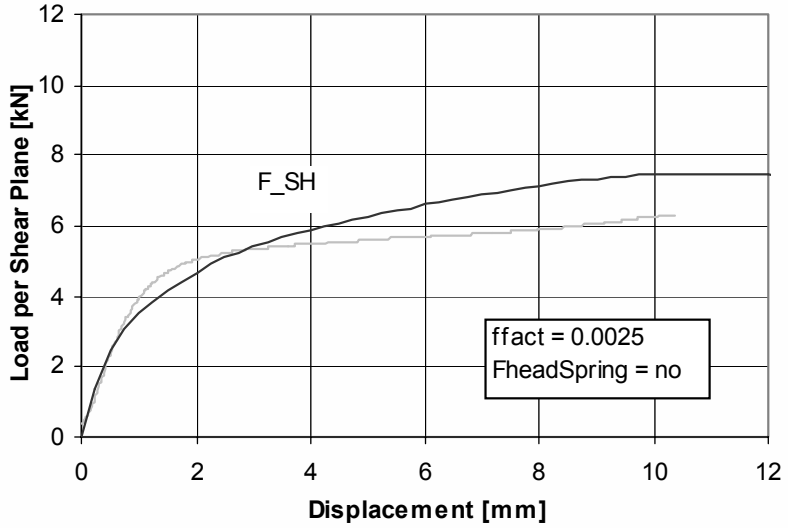
- **Fastener Material Fatigue:**
  - Linear Strength Reduction

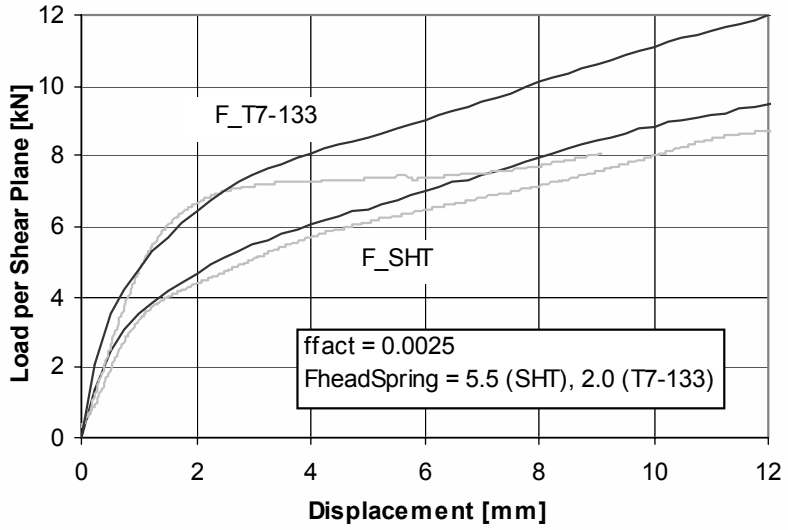


- **Calibration:**
  - **Fastener Strength** → Tensile Tests
  - **Embedment Behaviour, Fastener Head Spring** → Series D Tests

Analysis – Monotonic Results

- **Initial Stiffness:**
  - Good Representation
- **Yield Points:**
  - Underpredicted (G_SH / G_SHT)
- **Tangential Stiffness:**
  - Overpredicted (SHT, T7-XXX and T5-XXX)
  - → Fastener Head Stiffness
  - → Wood Failure
- **SH Best** Representation

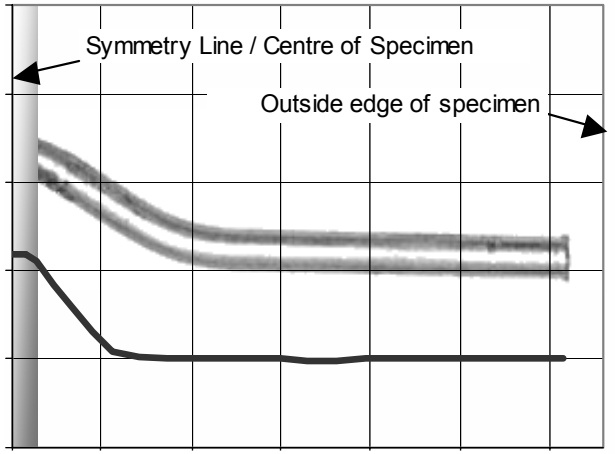


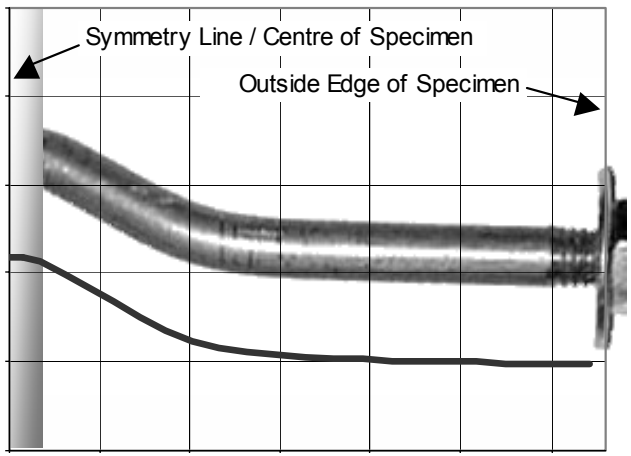


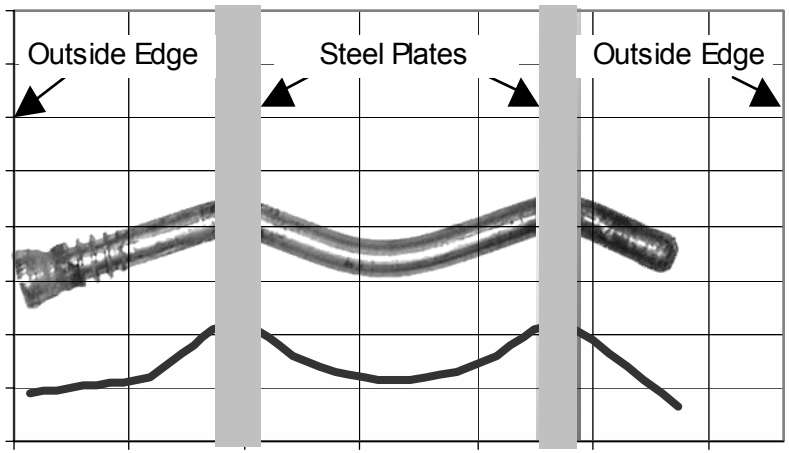
Analysis – Monotonic Results

Deformed Shapes:

- Well Predicted:
  - Withdrawal
  - Yield Hinge Locations
  - Shape

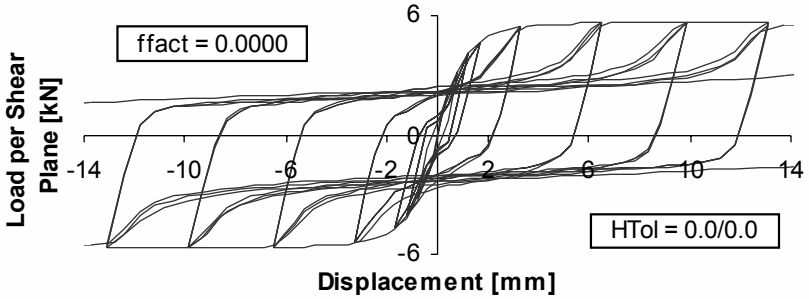


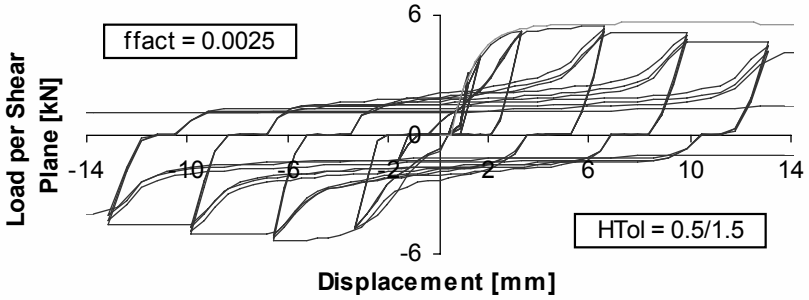


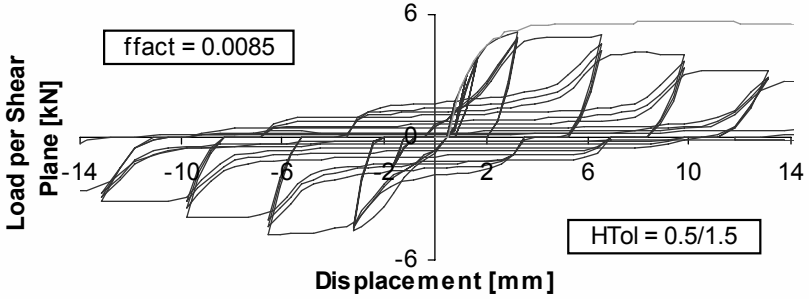


Analysis – Cyclic Results

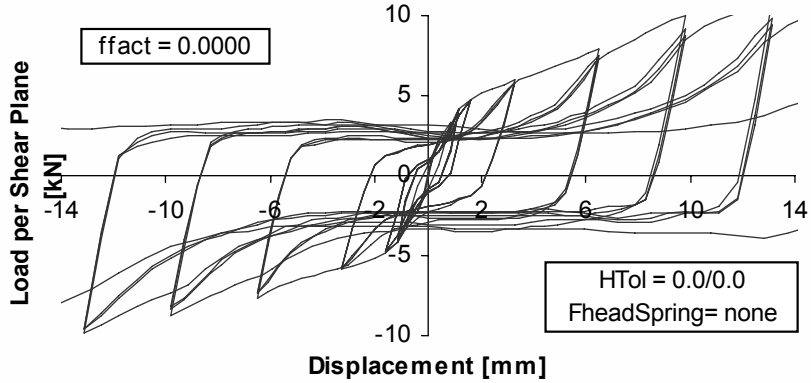
Effects from Modifications:

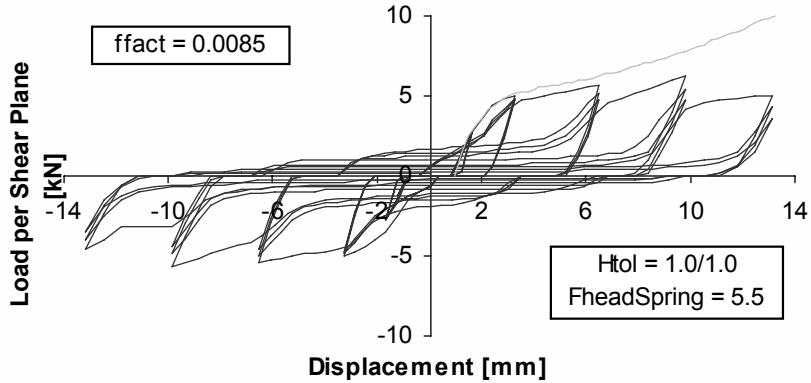






E_SH



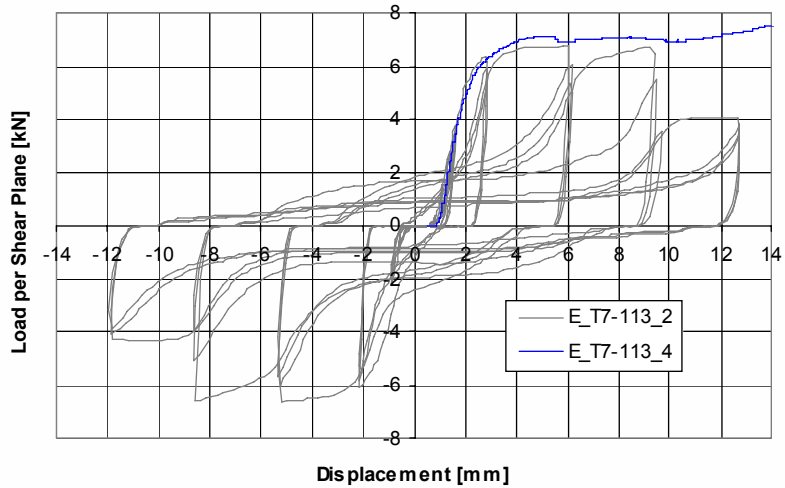


E_SHT

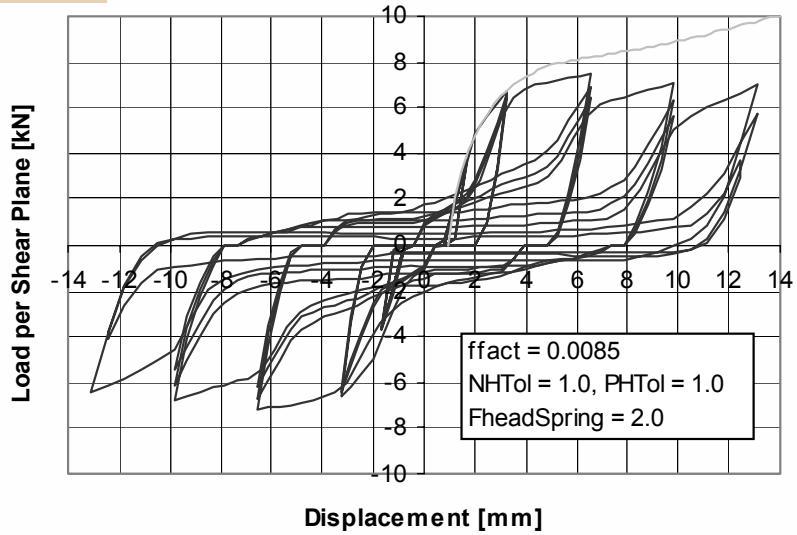
Analysis – Cyclic Results

- **Hysteresis Shapes well Predicted:**
  - SH Best
- **Modifications Necessary**
- **Fatigue Behaviour:**
  - Not as Catastrophic

Test:



Calculation:



Summary and Conclusions

- **Fastener Head:**
  - Increases Monotonic Strength, Resists Spreading of Wood
- **Cyclic Behaviour:**
  - Influenced by Fastener Head and Fastener Fatigue
- **Hole Tolerances:**
  - Influence Hysteresis Shape and Displacement Demand
- **Self-drilling Dowel** (SFS WS):
  - Improves Manufacturing, Strength, Stiffness
  - Cyclic Behaviour Comparable to Bolt
- **Finite-element Model:**
  - Inclusion of Modifications Essential
  - Simulated Behaviour Most Accurate for SH

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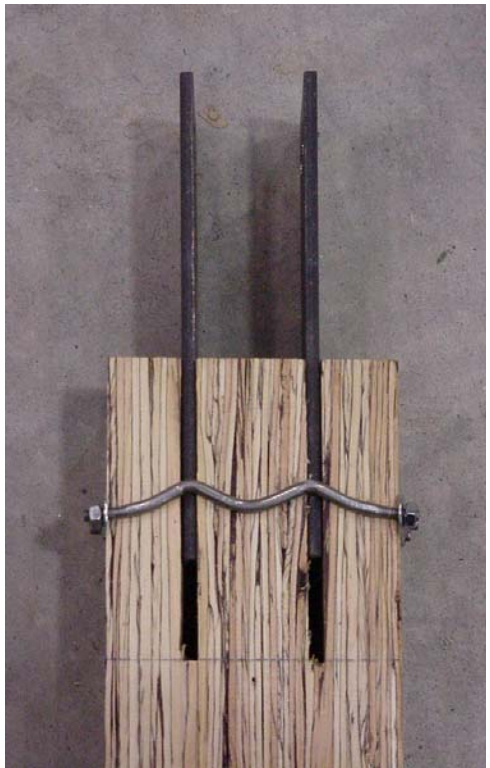

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