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

Alexander Schreyer
Ph.D. Student, Adj. Faculty, UMass

Frank Lam
Associate Professor, UBC

Helmut Prion
Associate Professor, UBC

www.alexschreyer.de/projects/masters/
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:**
  - Series D
  - Series E
  - Series F
  - Series G

- **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**

![Graph showing cyclic results](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

- **Fastener Head:**
  - Unidirectional Spring

**Without:**

**With:**

**Effect:**

Graphs showing load vs. displacement with and without modifications.
Analysis – Model Modifications

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

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

\[ \sigma_{y,\text{new}} = \sigma_y \cdot (1-\text{sffact}) \]
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:

- ffact = 0.0000
  - HTol = 0.0/0.0
  - FheadSpring = none

- ffact = 0.0025
  - HTol = 0.5/1.5

- ffact = 0.0085
  - HTol = 0.5/1.5

- ffact = 0.0085
  - HTol = 1.0/1.0
  - FheadSpring = 5.5

E_SH
Analysis – Cyclic Results

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

Test:

Calculation:

E_T7-113_2
E_T7-113_4

ffact = 0.0085
NHTol = 1.0, PHTol = 1.0
FheadSpring = 2.0

Displacement [mm]
Load per Shear Plane [kN]
Displacement [mm]
Load per Shear Plane [kN]
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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