Sheathing Braced Design of Wall Studs
February 2010 Update

www.ce.jhu.edu/bschafer/sheathedwalls

for
AISI Committee on Framing Standards
Design Methods Subcommittee
San Diego, CA
Overview

• Work Plan Summary

• Review of key results

• Discussion of current work and issues

• Conclusions

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Basic summary of work plan

• Literature summary
  - existing methods
  - existing predictive capabilities

• Computational modeling
  - to support testing
  - to support design method creation

• Phase 1 testing
  - 8’ wall, single stud type, different sheathing configurations, axial only
  - Fastener translational stiffness/strength tests
  - Single column with sheathing tests

• Phase 2 testing
  - Axial + bending tests, 8’ wall, final details TBD
  - Axial + bending single member tests, w/ sheathing

• Development of new design methods
  - identify limit states, potential design methodologies, calcs, examples

red = added to initial work plan
Basic summary of work products

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- Literature summary
  - existing methods (summary report, corrections to Simaan and Peköz)
  - existing predictive capabilities (Mathcad form)
- Computational modeling
  - to support testing (CUFSM and preliminary ABAQUS)
  - to support design method creation (reliability study on 2a, fastener spacing studies, fastener demands in bending due to torsion recently begun)
- Phase 1 testing
  - 8’ wall, single stud type, different sheathing, axial only (report and paper posted)
  - Fastener translational stiffness/strength tests (report and paper posted)
  - Single column with sheathing tests (report and paper posted)
- Phase 2 testing
  - Axial + bending tests, 8’ wall, final details TBD (trial knockdown test ready)
  - Axial + bending single member tests, w/ sheathing
- Development of new design methods
  - identify limit states, potential design methodologies, calcs, examples

red = added to initial work plan  blue = comment on work product
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AISI Design Methods

1962 AISI Design Manual
- Winter’s method
- discrete spring model

- Simaan and Peköz
- shear diaphragm model

2007 AISI-COFS Wall Stud Standard (S211)
- “simplified”
- discrete spring model
How a stud is braced
Stud bracing in more detail

\[ k_x, k_y, k_\phi \]

\[ k_\phi \text{ testing and design method} \]

\[ \text{bolted, turnbuckle for adjustment, angle free to twist, loading angle} \]
Component level stud-to-sheathing $k_x$

focus on $k_x$, translational stiffness, a la Winter’s test method

a) Front view  

b) Lateral view  

c) Closer view of the connection cross-section and board
Limiting case of Winter’s model?
An actual "strip" test

You can take Winter’s “mental model” too far! Local stiffness must be backed up by panel shear stiffness.
Sheathing $k_x$

\[ \tau(y) = G\theta(y) \]

\[ \theta(y) = \frac{d}{dy} \frac{x(y)}{L} = \frac{\pi}{L} \cdot \cos\left(\frac{\pi \cdot y}{L}\right) \]

\[ \tau(y) = \frac{G \cdot \pi}{L} \cdot \cos\left(\frac{\pi \cdot y}{L}\right) \]

\[ F(y) = (\tau_2 - \tau_1) \cdot wt / n \]

\[ k = \frac{F(y)}{x(y)} \]

\[ k = 2\pi \frac{Gwt}{Ln} \sin\left(\frac{\pi a}{2L}\right) \]
When sheathing $k$ matters?

- If $k_{\text{sheathing}} < 10k_{\text{fastener}}$... matters

$$k_{\text{total}}(\alpha) := \frac{1}{1 + \frac{1}{k_{\text{fastener}}} + \frac{1}{k_{\text{sheathing}}(\alpha)}}$$
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Single column testing

Testing Details
- 2', 4', 6' and 8'
- 362S162-68 (50 ksi)
- 362T125-68 (50 ksi)
- OSB (7/16 in.)
- #8 x 1 15/16”
- Gypsum (½ in.)
- #6 x 1 5/8”
Stud response w/ sheathing (L= 6ft)

6 feet stud with different combination of restrictions

- 2-BARE-BARE-1S6L-6.dat
- 7-BARE-BARE-2S6LT-6-T.dat
- 9-OSB-OSB-4S6LTSP-6-T-S-P.dat
- 10-GYP-GYP-5S6LTSP-6-T-S-P.dat
- 12-OSB-BARE-6S6LTSP-6-T-S-P.dat
- 13-OSB-GYP-7S6LTSP-6-T-S-P.dat

load (kip)

position (in)
single column test summary
single column test summary
Isolating composite action

Effect of bearing track on a plate, OSB-OSB

19.83%
Full-scale wall testing
Full-scale wall testing details

Sheathing configurations:
- Bare-Bare
- OSB-Bare
- Gyp-Gyp
- OSB-Gyp
- OSB-OSB

Details:
- 7/16 in. OSB w/ #8 screws
- ½ in. Gypsum w/ #6 screws
Typical P-Δ response and failure

Comparison between OSB-OSB and BARE-BARE walls

106 kips

56 kips
Summary of failure modes

Bare-Bare: FT

OSB-Bare: FT

OSB-Gyp: L + D
Gyp removed in picture

OSB-Gyp: L

OSB-OSB: L
Full-scale wall tests (P-Δ)

Comparison between different boards combination

load (kips)

position (in)
Sheathed single column tests are a surprisingly good proxy for the full-scale walls, indicating (a) little diaphragm action is needed to engage the local fastener stiffness (b) the end conditions are reasonably approximated in the single test even with short track, etc. (c) bracing force accumulation issues are not governing the capacity for the test walls,
Comparison with existing design

composite action

basic Spec. error

limit state missed

K error and basic Spec. error
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Current work

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• Literature summary
  – existing methods (summary report, corrections to Simaan and Peköz)
  – existing predictive capabilities (Mathcad form, being extended)

• Computational modeling
  – to support testing (CUFSM and ongoing ABAQUS)
  – to support design method creation (reliability study on 2a, fastener spacing studies, fastener demands including in bending due to torsion)

• Phase 1 testing
  – 8’ wall, single stud type, different sheathing, axial only (report and paper posted)
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blue = actively working on now..
Current work

- ABAQUS models of single and full-scale walls under axial compression. Objectives:
  - To determine explicitly how the fastener demands develop in the wall and to formally check the separation of the local fastener stiffness and the sheathing diaphragm stiffness
  - To develop an understanding of the additional fastener demands created through various direct loading mechanisms and support final selection of beam-column testing method

- Beam-column tests
  - Determination of loading method
  - Selection of test matrix and securing materials
    - Note material donations will be needed for the Phase 2 testing, this material request will be coming soon as we are already using old material to work out the loading method
Beam-column testing
Testing method implications

FIXED BASE $\delta, M, V$

PINNED BASE $\delta, M, V$
Testing method implications (cont.)

**FIXED BASE** $\delta$, $M$, $V$

**FIXED BASE, FREE TOP** $\delta$, $M$, $V$
Outstanding issues for needed PMTG meeting

- Test details for beam-column tests
  - Direct loading requires expensive addition to rig and introduces problematic shear to rig
  - Floating the top gives correct moment, but rig may not have enough movement and the allowed translation is a function of stiffness, method can be explored further
  - Pinned bottom is possible, single curvature is nice, seems even further removed from reality…
  - Testing a full-scale fully fixed mock-up specimen in the lab next week (should have been last week, thank you 3 ft of snow) to examine direct bending on top of specimen and provide guidance on best practices for this detail
  - Figure this all out with single column testing or go straight to full scale walls? Single column tests much faster, could try out a couple of details and/or do a wider range of specimens
  - Same specimen dimensions and sheathing…
  - Need full materials donation, materials request once details determined, this is long overdue
  - Note, modeling to allow fastener demands to be correlated to other testing details is underway. So, why not go forward with simplest approach after mock-up test details are worked out?
Outstanding issues for needed PMTG meeting

• What to do with global K values if K=1 is a big part of the lost economy. Ignore, guidance?...

• Translational stiffness for other details
  – Will do small study if materials fully donated

• Accurate or at least agreed upon G values for sheathing (gypsum board being the most problematic)

• What to do about incorporating gypsum board?
  – Explicitly shown humidity issues, existing data shows challenges under cyclic performance, distortional buckling in AISI-COFS basically ignores gyp
  – Gyp board effective in the conducted tests (not cycled, at normal RH levels)
  – Allow engineer to decide? (How to insure safety and level playing field) Look further into what wood allows? Declare gyp nonstructural and be done with it?
Conclusions

• Significant progress has been made towards the goal of creating a sheathing braced design method
  – component level experimental data completed
  – single member axial data completed
  – full-scale wall axial data completed
  – initial design methodology determined
  – development of axial load design method now underway

• Behavior of sheathing braced columns with dis-similar sheathing now better understood, and all member limit states L,D,F,FT have been observed in testing. (Restrained FT behavior gives some pause).

• Beam-column work is now underway to provide the final phase of the research.