Engineered Design of Structural Insulated Panels

Eric J. Tompos, P.E., S.E.
etompos@ntainc.com
Engineered Design of Structural Insulated Panels

- Overview
  - Sources of Design Information
  - Transverse Loads
  - Axial Loads
  - Shear Wall & Diaphragm Loads
Sources of Design Information

- SIP Manufacturer
  - Architectural/detail manuals showing typical construction and connections
  - Level of detail varies significantly between manufacturers
  - Prescriptive with little or no engineering properties
Sources of Design Information

- IRC Prescriptive Design
  - 2007 Supplement to the IRC, Section R614
  - Prescriptive method limited wind and seismic
  - Walls only, limited heights and thicknesses
Sources of Design Information

- **APA PDS Supplement 4-Design & Fabrication of Plywood Sandwich Panels**
  - Adopted by reference in IBC
  - Provides design method based on mechanics
  - Does not address important design issues such as creep and support effects
  - Does not provide typical material properties for design
Sources of Design Information

- Code Research Reports (NTA, ICC-ES)
  - Based on ICC-ES Acceptance Criteria AC04
  - Prescriptive with little or no engineering properties
  - Not clear what is based on testing vs. interpolation
  - Interpolation methods are not specified or provided

- NTA is working with SIPA and APA to develop engineering design standards
- NTA SIP design guide available
SIP Structural Behavior

- **Scope**
  - General behavior, actual values will vary—refer to manufacturer’s data
  - Symmetric SIPS
  - OSB facings
  - EPS, XPS or polyurethane cores
  - Non-structural splines (Block or Surface)
Flexural Behavior

- Based on transverse load testing with simple supports (ASTM E72)
- Elastic, $E$, and shear, $G$, moduli determined using procedures in ASTM D198
- Flexural stiffness governed by shear modulus of core
- Properties vary with orientation of OSB facings
  - 8-ft spans OSB may be in either direction
  - >8-ft spans OSB in strong direction
Flexural Behavior

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Deflection Calculation Methods

- Simply supported deflection equation with shear

\[ \Delta = \Delta_b + \Delta_s = \frac{5wL^4 \times 1728}{384E_b I} + \frac{wL^2}{4(h + c)G} \]

- FEA software
  - SIP moduli \((E, G)\) cannot be input directly. \(G\) typically based on Poisson’s ratio

\[ G = \frac{E}{2(1+\nu)} \]

- Shear deformations considered at nodes only, NOT between nodes, must discretize—read manual
Flexural Creep

- Deflection under sustained loads
- Creep models: Power model

\[ \delta_{FP} = 1 + D_1 t^{D_2} \]

- Deflection equation considering long term loads

\[ \Delta_T = K_{cr} \Delta_{LT} + \Delta_{ST} \]

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### Flexural Creep

<table>
<thead>
<tr>
<th>Material</th>
<th>$K_{cr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS, XPS Core SIP</td>
<td>4.0</td>
</tr>
<tr>
<td>Urethane Core SIP</td>
<td>7.0</td>
</tr>
<tr>
<td>Seasoned Lumber</td>
<td>1.5</td>
</tr>
<tr>
<td>OSB or Wet Lumber</td>
<td>2.0</td>
</tr>
<tr>
<td>Reinforced Concrete</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Transverse Shear Strength

- Factors affecting core shear strength
  - Core type (EPS, XPS, urethane)
  - Foam density and thickness
  - Additives (flame retardant, insecticide)
  - End support conditions
Transverse Shear Strength

![Graph showing the relationship between overall thickness and shear strength.](image)

Shear Strength, $F_v$ (psi)

Overall Thickness, $h$ (in.)

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Support Conditions

\[ C_v = 1.0 \]

Bearing Support

\[ C_v = 0.4 \]

Spline Support

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“Axial” Strength

- Axial tests in accordance with ASTM E72 include eccentricity equal to 1/6 the panel thickness
- Not Euler Buckling—instead Secant Formula

\[ \sigma_{\text{max}} = \frac{F}{A} \left( 1 + \frac{ec}{r^2} \sec \left( \sqrt{\frac{F}{EA}} \frac{L}{2r} \right) \right) \]

- For SIP parameters:

\[ \sigma_{\text{max}} \approx 2\sigma_{\text{axial}} \]
“Axial” Strength

- SIP capacity limited to one-half allowable compressive strength OSB facing under true axial load
- *APA N375-B Design Capacities of APA Performance Rated Structural Use Panels* provides allowable values for OSB facings
- ASTM E72 eccentricity intended to be “incidental”
“Axial” Strength

- Most eccentricities are not incidental and eccentricities greater than 1/6 the thickness often result (e.g. balloon framing)
Shear Wall & Diaphragm Strength

- Monotonic shear wall strength similar to conventional stud wall with equivalent edge fastener spacing
- Diaphragm strength similar to blocked diaphragm with equivalent edge fastener spacing
- Cyclic/seismic performance currently under debate
  - SIP panel structures have performed well during seismic events
  - Influence of sealants on cyclic response in laboratory
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