NTA INC. NTA TESTING LABORATORIES, INC.

Engineered Design of Structural Insulated Panels

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Engineered Design of Structural Insulated Panels

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

Sources of Design Information

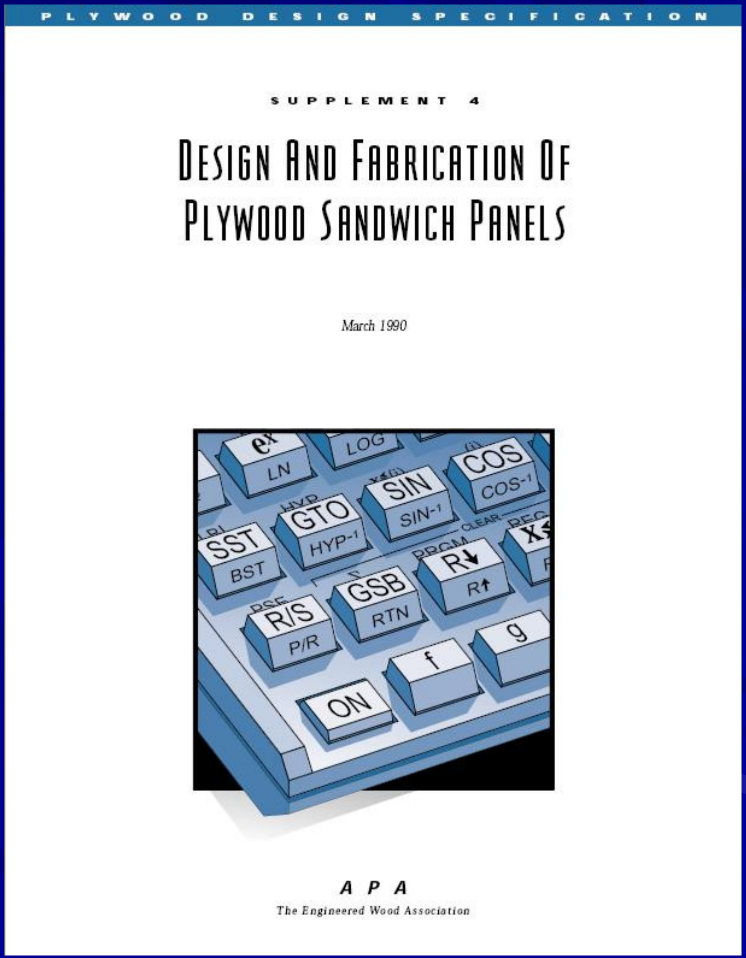
- SIP Manufacturer
  - Architectural/detail manuals showing typical construction and connections
  - Level of detail varies significantly between manufacturers
  - Prescriptive with little or no engineering properties

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

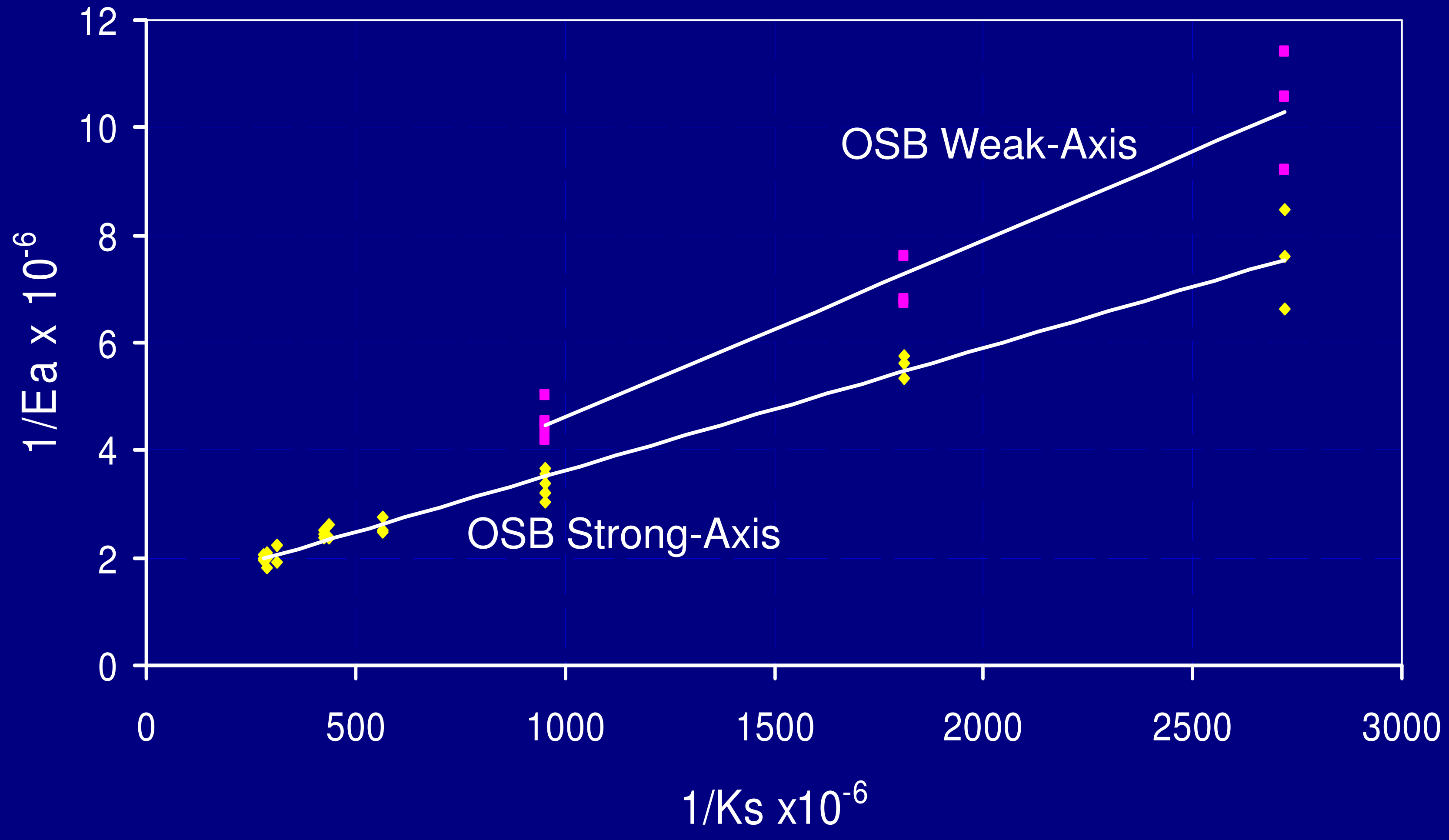
SIP Structural Behavior

- 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



Deflection Calculation Methods

- Simply supported deflection equation with shear

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

- 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[2]

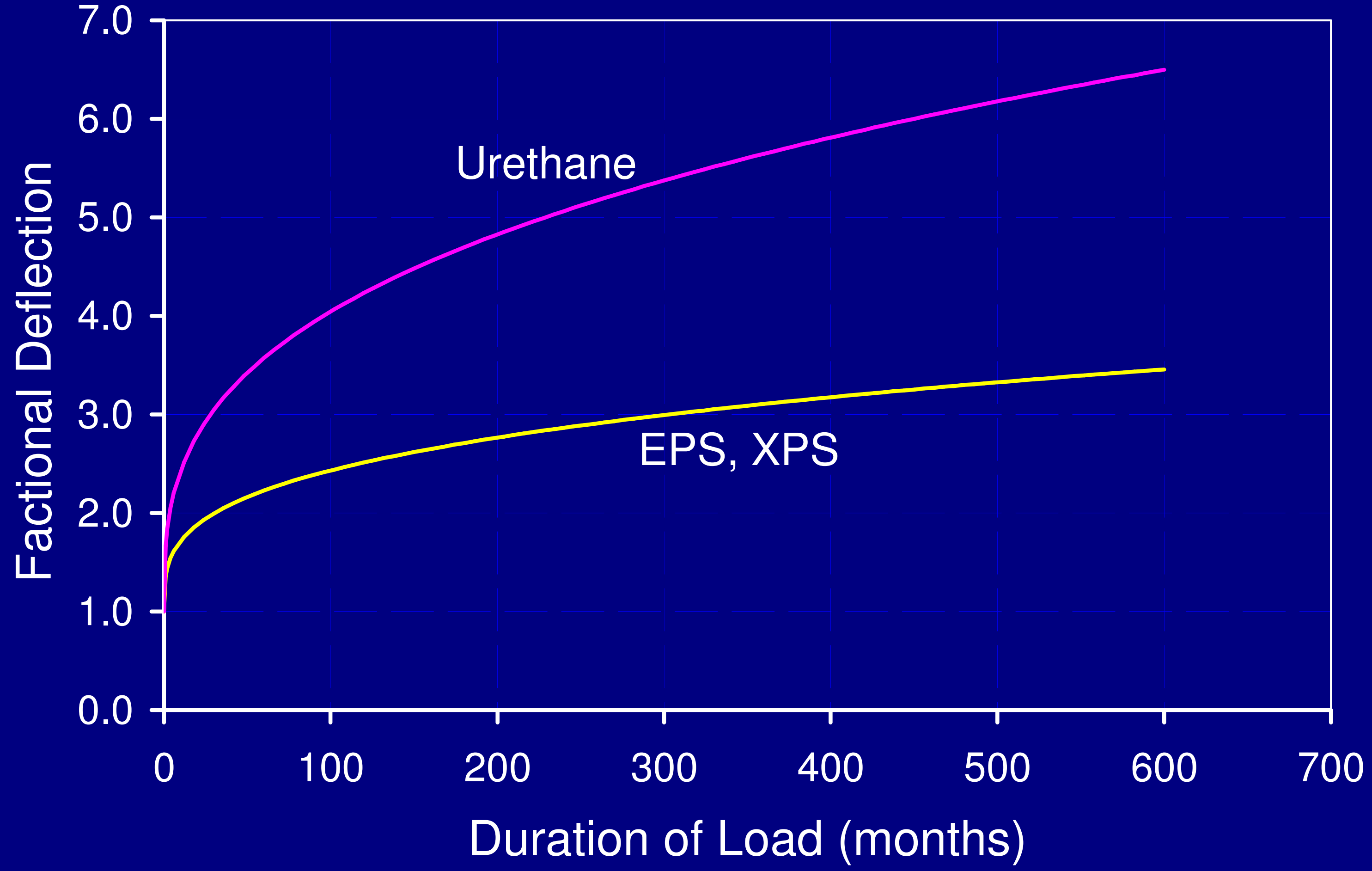
$$\delta_{FP} = 1 + D_1 t^{D_2}$$

- Deflection equation considering long term loads

$$\Delta_T = K_{cr}\Delta_{LT} + \Delta_{ST}$$

[2] Taylor, S.B., Manbeck, H. B., Janowiak, J. J., Hiltunum, D.R. "Modeling Structural Insulated Panel (SIP) Flexural Creep Deflection." *J. Structural Engineering*, Vol. 123, No. 12, December, 1997.

Flexural Creep



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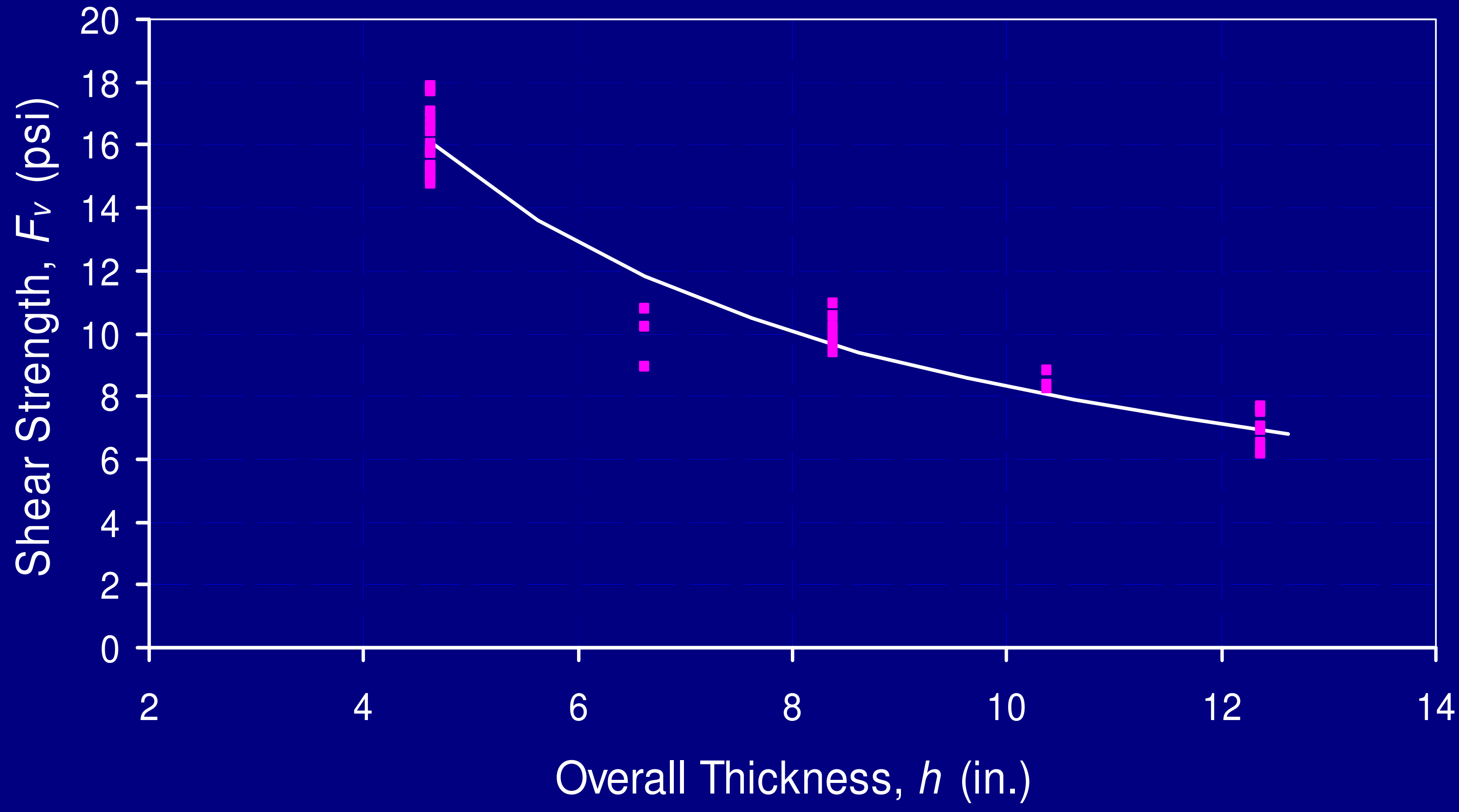
Flexural Creep

Material	K_{cr}
EPS, XPS Core SIP	4.0
Urethane Core SIP	7.0
Seasoned Lumber	1.5
OSB or Wet Lumber	2.0
Reinforced Concrete	2.0

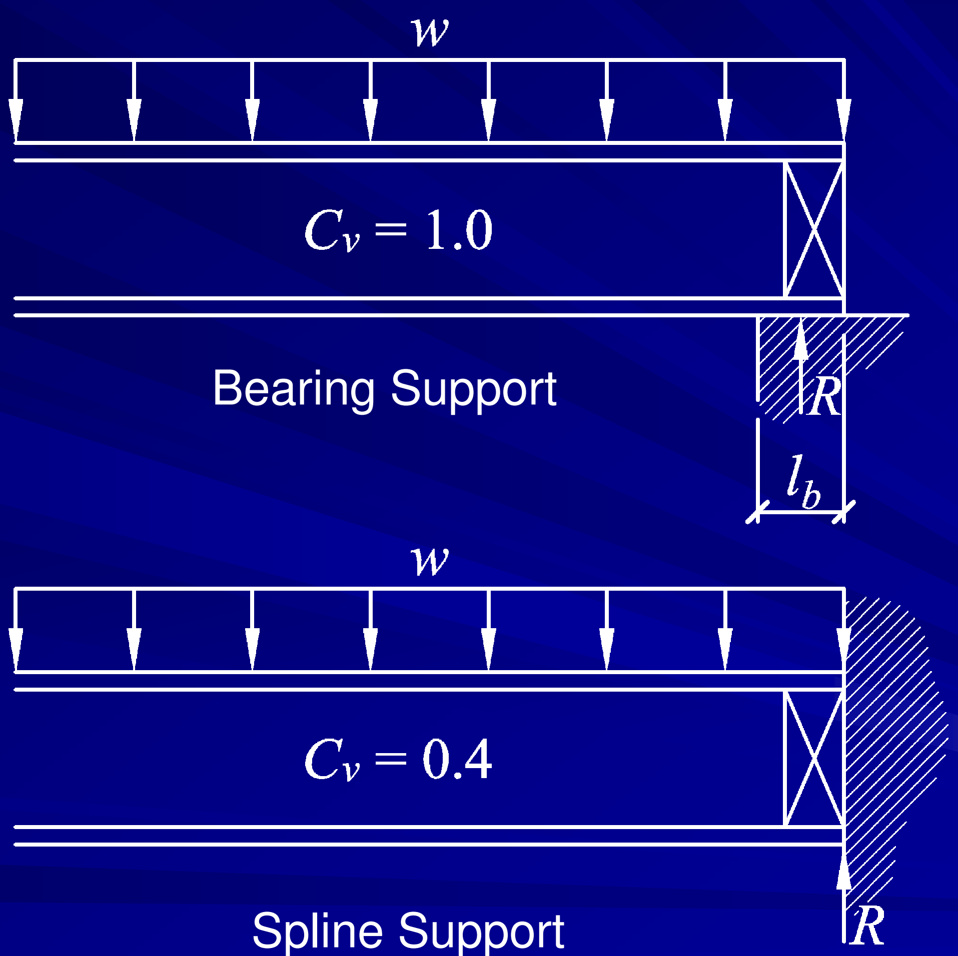
Transverse Shear Strength

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

Transverse Shear Strength



Support Conditions



“Axial” Strength

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

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

- For SIP parameters:

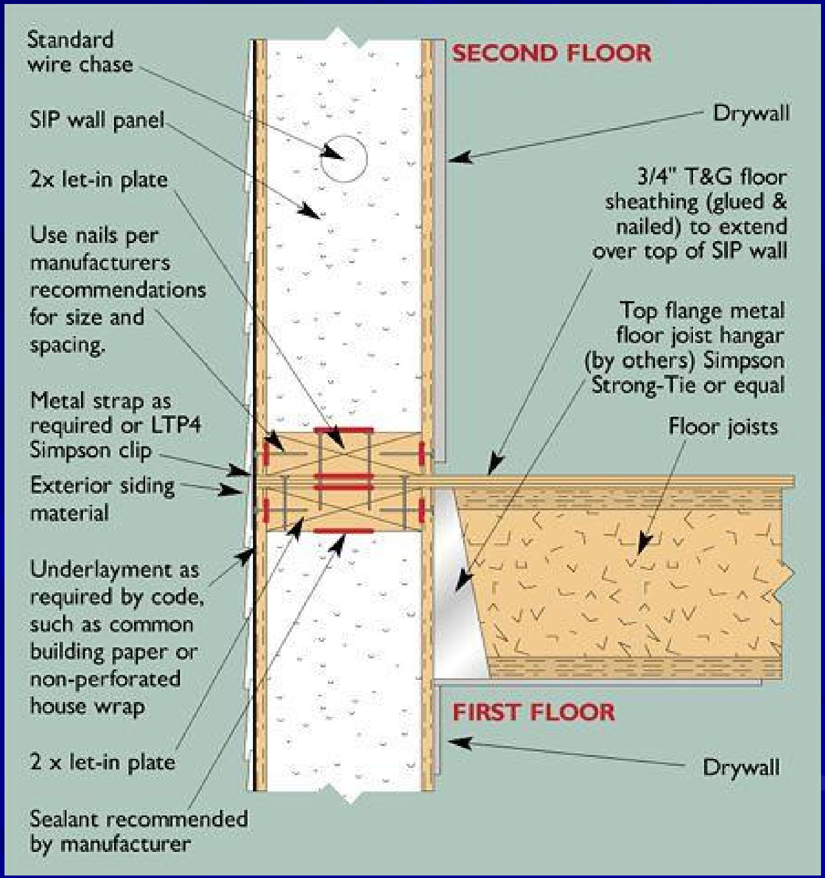
$$\sigma_{\max} \approx 2\sigma_{axial}$$

“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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