ENGINEERED DESIGN OF SIP PANELS USING NTA LISTING REPORT DATA

1. SCOPE

1.1. GENERAL

This document applies to structural insulated panels (SIPs), which shall be defined as a structural facing material with a foam core. This document does not apply to the design of reinforcement materials which may be incorporated into SIPs, such as dimensional lumber or cold-formed steel. All other materials shall be designed in accordance with the appropriate code adopted design standards.

It is intended that this document be used in conjunction with competent engineering design, accurate fabrication, and adequate supervision of construction. NTA, Inc. does not assume any responsibility for error or omissions in this document, nor for engineering design, plans or construction prepared from it. It shall be the final responsibility of the designer to relate design assumptions and reference design value, and to make design adjustments appropriate to the end use.

1.2. DESIGN PROCEDURES

This document provides requirements for the design of SIP panels by the Allowable Stress Design (ASD) method. The technical basis for this document is the *APA Plywood Design Specification Supplement 4—Design & Fabrication of Plywood Sandwich Panels*[1], which is adopted by reference in the International Building Code (IBC). Some provisions of the design guide have been modified to more closely model the actual behavior of the SIP system described in this report.

The design procedures provided herein generally assume uniform loads applied to a simply supported member. General loading and support conditions may be evaluated using rational analysis methods consistent with the methodology provided herein. If finite element analysis software is used, the designer must verify that the software considers shear deformations between model nodes as most commercially available finite element software packages only consider shear deformations at the nodes.

1.3. DESIGN LOADS

Minimum design loads shall be in accordance with the building code under which the structure is designed, or where applicable, other recognized minimum design load standards.

1.4. SERVICABILITY

Structural systems and members thereof shall be designed to have adequate stiffness to limit deflection and lateral drift. The deflections of structural members shall not exceed the limitations of the building code under which the structure is designed, or where applicable, other recognized minimum design load standards.

1.5. LOAD COMBINATIONS

Combinations of design load and forces, and load combinations factors, shall be in accordance with the building code under which the structure is designed, or where applicable, other recognized minimum design standards.

1.6. STRESS INCREASE

Duration of load increases in allowable stresses specified in the National Design Standard for Wood Construction (NDS) shall not be applied to SIP facings or core materials regardless of composition.

1.7. LIMITS OF USE

This document applies to NTA, Inc. listed SIP panels only and shall not be used with unlisted SIPs or SIPs listed/evaluated by other agencies. The design shall be limited to the specific panel thicknesses described in the listing report. This document shall not be applied to spans, heights, or aspect ratios not bounded by the limits of the listing report—extrapolation is not permitted.

2. NOTATION

Except where otherwise noted, the symbols used in this document have the following meanings:

Δ = Total deflection due to transverse load (in.)
Δ_{LT} = Total immediate deflection due to the long-term component of the design load (in.)
Δ_b = Deflection due to bending (in.)
Δ_c = Deflection of core under concentrated load applied to facing (in.)
Δ_i = Total immediate deflection due to application of a single design load acting alone (in.)
Δ_s = Deflection due to shear (in.)
Δ_{2nd} = Total immediate deflection considering secondary (P-delta) effects (in.)
A = Total cross sectional area of facings (in.^{2}/ft)
A_v = Shear area of panel. For symmetric panels $A_v = 6(h+c)$ (in.^{2}/ft)
c = Core thickness (in.)
C_e = Eccentric load factor, Section
C_{Fv} = Size factor for shear, Section 4.4.3
C_v = Shear support correction factor
e = Load eccentricity, measured as the distance from the centroid of the section to the line of action of the applied load (in.)
E_b = SIP modulus of elasticity under transverse bending (psi)
E_c = Elastic modulus of core under compressive load (psi)
E_f = Elastic modulus of facing under compressive load (psi)
F_c = Allowable facing compressive stress (psi)
F_t = Allowable facing tensile stress (psi)
F_v = Allowable shear stress (through thickness) (psi)
F_{vip} = Allowable shear load (in-plane) (plf)
G = SIP shear modulus (psi)
h = Overall SIP thickness (in.)
h_o = Reference SIP thickness for size correction factors (in.)
I = SIP moment of inertia (in.^{4}/ft)
I_f = Facing moment of inertia (in.^{4}/ft)
K_{cr} = Time dependent deformation (creep) factor for a specific load type, Section A3.5.3
L = Span length (ft)
L_v = Shear span length (ft)
m = Shear size factor exponent
M = Applied moment (in.-lbf/ft)
P = Applied axial or concentrated load (lbf/ft.)
P_{cr} = Allowable axial load (lbf/ft)
r Radius of gyration (in.)
S = SIP section modulus for flexure under transverse loads (in.^{3}/ft)
V = Applied shear force (through thickness) (lbf)
V_{ip} = Applied shear force (in-plane) plf
w = Uniform transverse load (psf)
y_c = Distance from the centroid to the extreme compression fiber (in.)
β = Parameter of relative stiffness

3. USE CONSIDERATIONS

3.1. LOAD DURATION

Duration of load increases in allowable stress shall not be applied to SIP facings or cores. Duration of load increases may be applied to the design of connections and wood reinforcement as permitted in applicable material design specifications.

3.2. MOISTURE

This document applies to SIP panels used under dry service conditions. For SIP facings of wood or wood composites the in-use moisture content shall not exceed 19%.

3.3. TEMPERATURE

This Document applies to SIP panels used as structural members were sustained temperatures do not exceed 100ºF.

4. BENDING MEMBERS

4.1. GENERAL

Each SIP panel subjected to transverse loads shall be of sufficient size and capacity to carry the applied loads without exceeding the allowable design values specified herein.

4.2. SPAN OF BENDING MEMBERS

For simple, continuous and cantilevered bending members, the design span shall be taken as the distance from face to face of support. When no bearing is provided, such as when a panel is supported by a spline only (C_v < 1.0), the design span shall extend the full height/length of the panel.

4.3. BENDING MEMBERS—FLEXURE

4.3.1. GENERAL

Panel flexural strength under transverse loading shall satisfy both equations below:

$$M \le F_t S \quad \textbf{(Eqn. 4.3.1a)}$$

$$M \le F_c S \quad \textbf{(Eqn. 4.3.1b)}$$

4.4. BENDING MEMBERS—SHEAR

4.4.1. GENERAL

The actual shear stress parallel to the facing at the core to facing interface shall not exceed the adjusted shear design value.

4.4.2. SHEAR DESIGN EQUATIONS

The panel shear strength under transverse loading shall satisfy the following equation:

$$V \le F_v C_{Fv} C_v A_v \quad \textbf{(Eqn. 4.4.2)}$$

4.4.3. SHEAR SIZE ADJUSTEMENT FACTOR, C_{Fv}

The allowable shear strength shall be multiplied by a adjustment factor for the depth of the panel. The shear size adjustment factor shall be calculated using Equation 4.4.3.

$$C_{Fv} = \left(\frac{h_o}{h}\right)^m \quad \textbf{(Eqn. 4.4.3)}$$

4.4.4. SUPPORT ADJUSTEMENT FACTOR, C_v

4.4.4.1. For panel ends supported by full bearing on one facing and uniform loads applied to the opposite facing, the shear adjustment factor, C_v = 1.0 (see Figure A4.4.4).

4.4.4.2. For panel ends without bearing, supported by a top/bottom spline only, with uniform loads applied to either facing, the shear adjustment factor, C_v, shall be based on testing specific to the following parameters (see Figure A4.4.4):

1. Panel manufacturer;

2. Spline type, as it relates to the withdrawal/pullout strength of the fasteners (e.g. specific gravity for wood plates);
3. Fastener type and penetration.

4.4.4.3. Where C_v is less than 1.0, the allowable shear strength may be increased if the spline/fastener combination has a design withdrawal/pullout strength greater than the design withdrawal/pullout strength of the C_v assembly. The increase in strength shall not exceed the difference in the design withdrawal/pullout strength between the stronger assembly and the C_v assembly

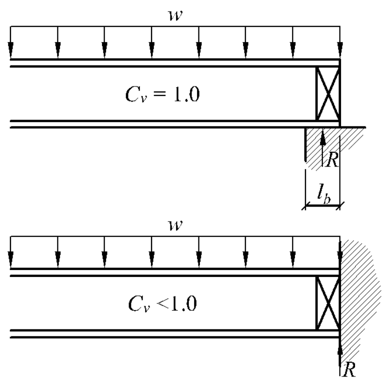

Figure 4.4.4: C_v Support Conditions

4.4.5. SHEAR DESIGN FORCE

When calculating the shear force, *V*, in bending members:

a) For panels supported by full bearing on one facing and uniform loads applied to the opposite facing (C_v = 1.0), uniformly distributed loads within a distance from the supports equal to the depth of the panel, *h*, shall be permitted to be ignored.
b) For all other support and loading conditions (C_v < 1.0), no load applied to the panel may be ignored and *V* shall be taken as the full reaction at the support under consideration.

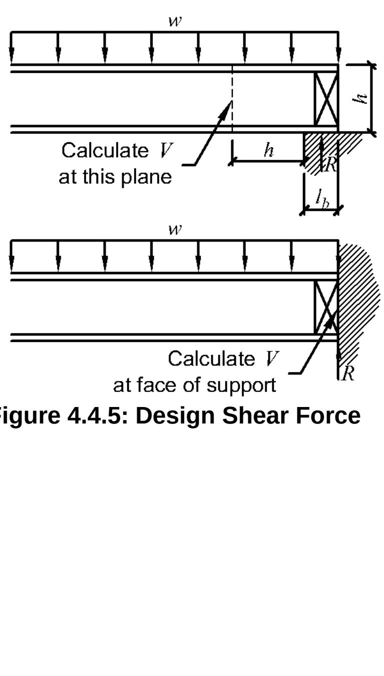

Figure 4.4.5: Design Shear Force

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4.5. BENDING MEMBERS—DEFLECTION

4.5.1. GENERAL

Deflection shall be calculated by standard methods of engineering mechanics considering both bending deflections and shear deflections.

4.5.2. DEFLECTION EQUATIONS

Deflection of a simply supported panel under uniform transverse load only shall be calculated as follows:

$$\Delta = \Delta_b + \Delta_s = \frac{5wL^4 \times 1728}{384 E_b I} + \frac{3}{2}\frac{wL^2}{A_v G} \quad \textbf{(Eqn. 4.5.2a)}$$

Deflections for panels subjected to combined loads shall consider the effects of axial load (P-delta effects). The total deflection of panels under combined loads may be approximated as follows.

$$\Delta_{2nd} = \frac{\Delta}{1 - P/P_{cr}} \quad \textbf{(Eqn. 4.5.2a)}$$

4.5.3. LONG-TERM LOADING

Where deflection under long-term loading must be limited, the total deflection, including creep effects shall be calculated as follows:

$$\Delta_T = \sum K_{cr_i} \Delta_i \quad \textbf{(Eqn. 4.5.3)}$$

Table 1: *Kcr* Based on Load Type[1]

Load Type[2]	EPS/XPS Core	Urethane Core
D, F, H, T	4.0	7.0
L	3.0	5.0
E, W, S, R, L_r, F_a	1.0	1.0

[1] Table values are for OSB facings used under dry service conditions.
[2] Load types are as defined in ASCE 7-05.

4.5.4. DEFLECTION LIMITS

The total deflection of structural or non-structural bending members, including consideration for long-term loading, shall not exceed the more restrictive of the following:

a) the span divided by 120 (L/120);
b) the limitations of the building code under which the structure is designed;
c) or, other recognized minimum design load standards.

4.6. BEARING AND CONCENTRATED LOADS ON FACINGS

4.6.1. MINIMUM SUPPORT WIDTH

A minimum support width of 1.5-inches shall be provided at all supports where the SIP is designed for bearing (C_v = 1.0). The bearing support shall be continuous along the end of the panel.

4.6.2. BEARING STREGNTH

4.6.2.1. Where a full-depth structural spline is provided at a point of bearing, the bearing strength shall not exceed the design bearing strength of the facings or spline, whichever is less.

4.6.2.2. Where a full-depth structural spline is not provided at a point of bearing and the bearing face of the panel is supported by the core only. The allowable bearing strength shall be limited to the load producing a long-term total compression of the core equal to 1/8-inch. Long term deflections shall be calculated in accordance with Section 4.5.3. The core compression deflection shall be calculated using the component material properties of the facing and the core considering the facing as a beam on an elastic foundation. Formulas for common cases (Figure 4.6.2.2) are provided in Equations 6.2.2.2a and 6.2.2.2b. Equations are for loads uniformly applied along the end of the panel.

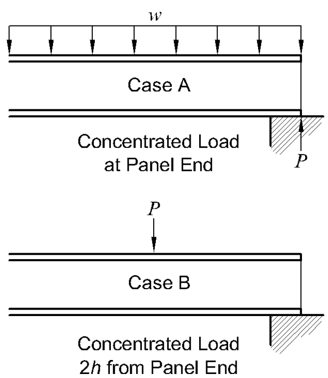

Figure 4.6.2.2: Bearing on Facings

Case A: $$\Delta_c = \frac{P}{4E_f I_f \beta^3}$$ **(Eqn. 4.6.2.2a)**

Case B: $$\Delta_c = \frac{P}{8E_f I_f \beta^3}$$ **(Eqn. 4.6.2.2b)**

$$\beta = \sqrt[4]{\frac{3E_c}{E_f I_f c}}$$ **(Eqn. 4.6.2.2c)**

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5. COMPRESSION MEMBERS

5.1. GENERAL

Each SIP panel subjected to compressive loads shall be of sufficient size and capacity to carry the applied loads without exceeding the allowable design values in this section.

5.1.1. COMPRESSION MEMBERS—LOAD ECCENTRICITY

The panel compression strength under axial loading shall satisfy the following equation:

$$P \le P_e \quad \textit{where} \quad P_e = C_e F_c A_f$$ **(Eqn. 5.1.1a)**

The eccentric load factor shall be calculated using Equation 5.1.1b considering a minimum eccentricity equal to not less than one-sixth the overall panel thickness ($e \ge h/6$).

$$C_e = \frac{1}{1 + \frac{e y_c}{r^2} \sec\left[\frac{12L}{2r}\sqrt{\frac{P}{A_f E_b}}\right] + \frac{P e y_c}{2 A_v G I}}$$ **(Eqn. 5.1.1b)**

5.1.2. COMPRESSION MEMBERS—GLOBAL BUCKLING

The critical buckling load for a pinned-pinned column under axial loading shall satisfy the following equation:

$$P \le P_{cr} \quad \textit{where} \quad P_{cr} = \frac{\pi^2 E_b I}{3 \times (12L)^2 \left[1 + \frac{\pi^2 E_b I}{(12L)^2 \times A_v G}\right]}$$ **(Eqn. 5.1.2)**

5.1.3. COMPRESSION MEMBERS—BEARING

The axial compressive load shall not exceed the bearing strength of the supporting materials. The bearing strength of the supporting materials shall be verified in accordance with the appropriate design specification. Where one or more of the SIP facings are not in bearing, the connection between the facings and the spline shall be designed to transfer the full load from the facings to the plate.

6. TENSION MEMBERS

6.1. GENERAL

A continuous load path shall be provided to transfer tension forces through the structure in a way that does not impart tensile loads to the SIP panel facings or core.

7. COMBINED LOADS

7.1. GENERAL

Panels subjected to combined loads shall of sufficient size and capacity to carry the applied loads without exceeding the allowable design values in this section.

7.1.1. COMBINED COMPRESSION, TRANSVERSE BENDING AND IN-PLANE SHEAR

Panel strength under combined axial compression, transverse bending and in-plane shear shall satisfy the following interaction equations:

$$\frac{P}{P_e} + \frac{M_{\max}}{F_c S} + \frac{V_{ip}}{F_{vip}} \leq 1.0 \qquad \textbf{(Eqn. 7.1.1a)}$$

$$\frac{P}{P_{cr}} + \frac{M_{\max}}{F_c S} + \frac{V_{ip}}{F_{vip}} \leq 1.0 \qquad \textbf{(Eqn. 7.1.1a)}$$

For simply supported beam columns M_{max} shall equal:

$$M_{\max} = 1.5wL^2 + P\Delta_{2nd} \qquad \textbf{(Eqn. 7.1.1c)}$$

8. CONNECTIONS

8.1. GENERAL

Connections between SIP panels, splines, plates, and non-SIP assemblies shall be designed in accordance with the appropriate material design standard referenced in the applicable building code.

9. SHEAR WALLS AND DIAPHRAGMS

9.1. GENERAL

SIP panel shear walls and diaphragms acting as elements of the lateral force-resisting system shall be designed in accordance with this section.

9.2. DEFINITIONS

Reserved for future use.

9.3. SHEAR WALLS

Reserved for future use.

9.3.1. DEFINITIONS

Reserved for future use.

9.3.2. SHEAR WALL ANCHORAGE

Reserved for future use.

9.3.3. SHEAR WALL STRENGTH

Reserved for future use.

9.3.4. SHEAR WALL DEFLECTION

Reserved for future use.

9.4. DIAPHRAGMS

Reserved for future use.

10. REFERENCES

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