Appendix

11-A. Strength and Deflection

(1) Flexural Strength Design

Strength design are made assuming that the flexural strength of the panel is totally dependent on aluminum skins.

This means that if the stress exerted on the aluminum skins, which is determined by both supporting and loading conditions, is within the range of aluminum strength, the plastic deformation of the panel will not occur.

Strength of the aluminum skin (3105H14): 22.0×10^3 psi = 22.0 ksi

- How to obtain the stress in aluminum skin. The magnitude of stress depends on the supporting and loading conditions. The stress calculation method depending on the conditions are given in Table 11-1 and 11-2.

NB. t^2 in the Tables are given in the formula below.

$$t^2 = (t_{AP}{}^3 - t_{PE}{}^3)/t_{AP}$$

Where, t: apparent thickness of AP (mm)

t_{AP}: AP thickness (mm)

t_{PE}: core polyethylene thickness (mm)

The calculated values of t^2 for each AP brand are given in Table 11-3.

Table 11-3. Square of apparent Alpolic thickness (square inches)

t_{AP} (mm)	3	4	6
$t^2 (\times 10^{-3}\ in^2)$	9.8	14.3	23.5

(Example calculation)

When Alpolic is 3mm thick, panel size being 3' x 3' square, supporting conditions being 4 sides fixed and wind load w=40 lbf/ft^2, does the plastic (permanent) deformation of Alpolic occur?

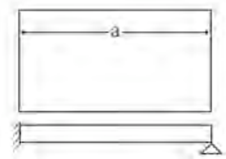
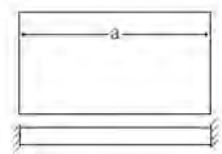
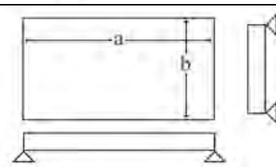
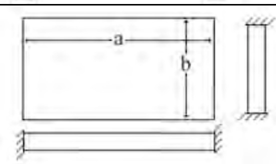
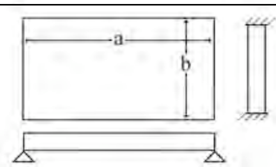
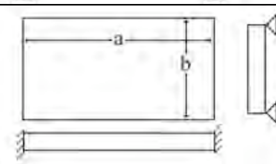
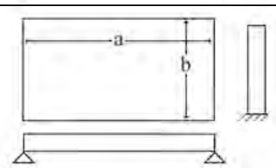
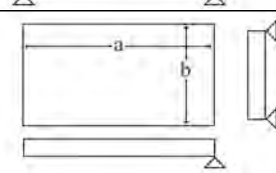
According to Table 11-1, case No. 6 a/b=1. Therefore β=0.3078.

$$\sigma_{MAX} = \beta w b^2/t^2 = 0.3078 \times 40/(12 \times 12) \times (3 \times 12)^2/(9.8 \times 10^{-3})$$

$$= 11.3 \times 10^3 \text{ psi} < 22.0 \times 10^3 \text{ psi (strength)}$$

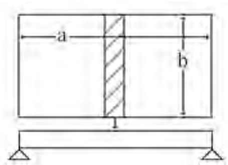
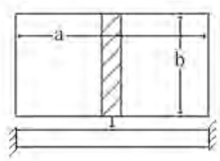
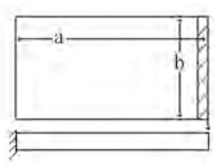
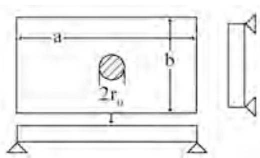
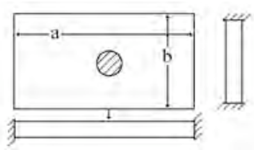
Therefore, 3mm thick Alpolic panel is all right in this case.

Table 11-1. Skin Stress Calculation When The Load is Uniformly Distributed

<table>
<tr><th>No.</th><th>Support Condition</th><th>Conditions Illustrated</th><th>Maximum Skin Stress (σ_{MAX}) Formula</th></tr>
<tr><td>1</td><td>1 side fixed,
3 sides free</td><td></td><td>$\sigma_{MAX} = \frac{3wa^2}{t^2}$</td></tr>
<tr><td>2</td><td>2 sides simply supported,
2 sides free</td><td></td><td>$\sigma_{MAX} = \frac{3}{4} \cdot \frac{wa^2}{t^2}$</td></tr>
<tr><td>3</td><td>1 side fixed opposite side simply supported,
2 sides free</td><td></td><td>$\sigma_{MAX} = \frac{3}{4} \cdot \frac{wa^2}{t^2}$</td></tr>
<tr><td>4</td><td>2 sides fixed,
2 sides free</td><td></td><td>$\sigma_{MAX} = \frac{1}{2} \cdot \frac{wa^2}{t^2}$</td></tr>
<tr><td>5</td><td>4 sides simply supported</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td><td>3.0</td></tr><tr><td>β</td><td>0.2874</td><td>0.3762</td><td>0.4530</td><td>0.5172</td><td>0.5688</td><td>0.6102</td><td>0.7134</td></tr></table></td></tr>
<tr><td>6</td><td>4 sides fixed</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td><td>∞</td></tr><tr><td>β</td><td>0.3078</td><td>0.3834</td><td>0.4356</td><td>0.4680</td><td>0.4872</td><td>0.4974</td><td>0.500</td></tr></table></td></tr>
<tr><td>7</td><td>Longer sides fixed, shorter sides simply supported</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td><td>∞</td></tr><tr><td>β</td><td>0.4182</td><td>0.4086</td><td>0.4860</td><td>0.4968</td><td>0.4971</td><td>0.4973</td><td>0.500</td></tr></table></td></tr>
<tr><td>8</td><td>Longer sides simply supported,
shorter sides fixed</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td><td>∞</td></tr><tr><td>β</td><td>0.4182</td><td>0.5208</td><td>0.5988</td><td>0.6540</td><td>0.6912</td><td>0.7146</td><td>0.750</td></tr></table></td></tr>
<tr><td>9</td><td>1 longer side fixed, another longer side free, shorter sides simply supported</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.5</td><td>2</td><td>3</td><td>∞</td></tr><tr><td>β</td><td>0.714</td><td>1.362</td><td>1.914</td><td>2.568</td><td>3.00</td></tr></table></td></tr>
<tr><td>10</td><td>1 shorter side free, other sides simply supported</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$<table><tr><td>a/b</td><td>1</td><td>1.5</td><td>2</td><td>4</td></tr><tr><td>β</td><td>0.67</td><td>0.77</td><td>0.79</td><td>0.80</td></tr></table></td></tr>
</table>

(note) w: unit area load (lbf/ft^2)

Table 11-2. Skin Stress Calculation When The Load Is Concentrated

<table>
<tr><th>No.</th><th>Support Condition</th><th>Conditions Illustrated</th><th>Maximum Skin Stress (σ_{MAX}) Formula</th></tr>
<tr><td>1</td><td>2 sides simply supported,
2 sides free,
center load</td><td></td><td>$\sigma_{MAX} = \frac{3}{2} \cdot \frac{Wa}{bt^2}$</td></tr>
<tr><td>2</td><td>2 sides fixed,
2 sides free,
center load</td><td></td><td>$\sigma_{MAX} = \frac{3}{4} \cdot \frac{Wa}{bt^2}$</td></tr>
<tr><td>3</td><td>1 side fixed,
other sides free,
tip load</td><td></td><td>$\sigma_{MAX} = 6 \cdot \frac{Wa}{bt^2}$</td></tr>
<tr><td>4</td><td>4 sides simply supported,
concentrated
center load</td><td></td><td>$\sigma_{MAX} = 0.145 \frac{W}{t^2} \left[4.3 \log \frac{2b}{\pi r_0} + 1 - 3.3\beta \right]$
<table>
<tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td></tr>
<tr><td>β</td><td>0.565</td><td>0.350</td><td>0.211</td><td>0.125</td><td>0.073</td><td>0.072</td></tr>
</table></td></tr>
<tr><td>5</td><td>4 sides fixed,
concentrated
center load</td><td></td><td>$\sigma_{MAX} = \beta \cdot \frac{W}{t^2}$
<table>
<tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td><td>1.8</td><td>2.0</td></tr>
<tr><td>β</td><td>0.7542</td><td>0.8940</td><td>0.9624</td><td>0.9906</td><td>1.000</td><td>1.004</td></tr>
</table></td></tr>
</table>

(note) W: load (lbf)

longer span (inch)

shorter span (inch)

(2) Deflection Calculation

Alpolic is a laminated sandwich composite panel characterized by lightweight and rigidity. Therefore the deflection can be minimized.

The deflection of Alpolic can be calculated as follows. The magnitude of actual deflection under load is given in previous section, (1) Flexural strength design.

(a) Deflection by uniformly-distributed load

When the panel is subject to uniformly-distributed load (dead weight of horizontal panel, wind load, etc.), the deflection can be given by the formula below:

$$\delta_{MAX} = \alpha \bullet wb^4/(E_{Ap} \bullet t_{Ap}^3)$$

Where, δ_{MAX}: maximum deflection (inches)

α: constant given by supporting conditions

E_{Ap}: flexural modulus of Alpolic (psi)

t_{Ap}: Alpolic thickness (mm)

w: unit area load (lbf/ft^2)

b: span (ft)

The required values for calculation are given in Table 11-4 and Table 11-5.

Table 11-4. Flexural modulus E_{Ap} and $E_{Ap} \bullet t_{Ap}^3$

t_{Ap} (mm)	E_{Ap}(psi)	$E_{Ap} \bullet t_{Ap}^3$ (lbf • in)
3	7110×10^3	11.7×10^3
4	5770×10^3	22.5×10^3
6	4220×10^3	55.6×10^3

(Example calculation)

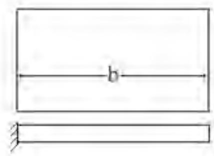
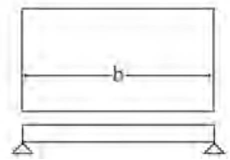
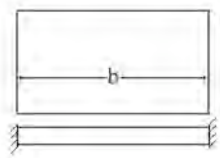
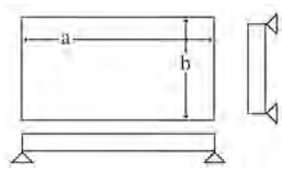
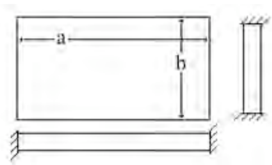
When Alpolic is 3mm thick, panel size being 3½' x 3½' square, supporting conditions being 4 sides fixed and wind load $w=30\ lbf/ft^2$, how much does Alpolic deflect?

According to Table 11-5, case No. 5, a/b=1 $\therefore \alpha=0.0138$,

$$\delta_{MAX} = \alpha \bullet wb^4/(E_{Ap} \bullet t_{Ap}^3) = 0.0138 \times 30/(12 \times 12) \times (3.5 \times 12)^4 / (11.7 \times 10^3)$$

$$= 0.765" (\doteqdot 19.4mm)$$

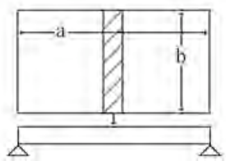
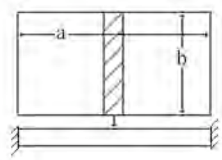
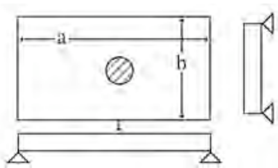
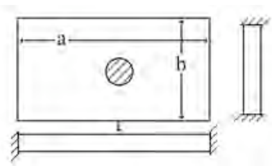
Table 11-5. Constants by supporting condition when the load is uniformly Distributed

<table>
<tr><th>No.</th><th>Support Condition</th><th>Conditions Illustrated</th><th>Constant: α</th></tr>
<tr><td>1</td><td>1 side fixed,
3 sides free</td><td>
</td><td>$\alpha = 1.50$</td></tr>
<tr><td>2</td><td>2 sides simply supported,
2 sides free</td><td>
</td><td>$\alpha = 0.156$</td></tr>
<tr><td>3</td><td>2 sides fixed,
2 sides free,</td><td>
</td><td>$\alpha = 0.0313$</td></tr>
<tr><td>4</td><td>4 sides simply supported</td><td>
</td><td>
<table>
<tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td></tr>
<tr><td>α</td><td>0.044</td><td>0.062</td><td>0.077</td><td>0.0906</td></tr>
</table>
<table>
<tr><td>a/b</td><td>1.8</td><td>2.0</td><td>3.0</td><td>∞</td></tr>
<tr><td>α</td><td>0.1017</td><td>0.1110</td><td>0.1335</td><td>0.1422</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>4 sides fixed</td><td>
</td><td>
<table>
<tr><td>a/b</td><td>1</td><td>1.2</td><td>1.4</td><td>1.6</td></tr>
<tr><td>α</td><td>0.0138</td><td>0.0188</td><td>0.0226</td><td>0.0251</td></tr>
</table>
<table>
<tr><td>a/b</td><td>1.8</td><td>2.0</td><td>∞</td></tr>
<tr><td>α</td><td>0.0267</td><td>0.0277</td><td>0.0284</td></tr>
</table>
</td></tr>
</table>

(b) Deflection by concentrated load

When the panel is subject to concentrated load, the deflection can be given by the formula below:

Table 11-6. Constants by supporting condition when the load is uniformly Distributed

No.	Support Condition	Conditions Illustrated	Maximum Skin Stress (σ_{MAX}) Formula
1	2 sides simply supported, 2 sides free, center load		$\delta_{MAX} = 0.25 \bullet \dfrac{Wa^3}{bE_{Ap} \bullet t_{Ap}^3}$
2	2 sides fixed, 2 sides free, center load		$\delta_{MAX} = 0.0625 \bullet \dfrac{Wa^3}{bE_{Ap} \bullet t_{Ap}^3}$
3	4 sides simply supported, concentrated center load		$\delta_{MAX} = \alpha \bullet \dfrac{Wb^2}{E_{Ap} \bullet t_{Ap}^3}$ a/b: 1.0, 1.2, 1.4, 1.6, 1.8, 2.0 β: 0.128, 0.148, 0.158, 0.172, 0.177, 0.1805
4	4 sides fixed, concentrated center load		$\delta_{MAX} = \alpha \bullet \dfrac{Wb^2}{E_{Ap} \bullet t_{Ap}^3}$ a/b: 1.0, 1.2, 1.4, 1.6, 1.8, 2.0 β: 0.0611, 0.0705, 0.0754, 0.0777, 0.0786, 0.0788

Where, δ_{MAX}:	maximum deflection (inches)
α:	constant given by supporting conditions
E_{Ap}:	flexural modulus of Alpolic (psi)
t_{Ap}:	Alpolic thickness (mm)
W:	concentration load (lbf)
a:	larger span (inches)
b:	shorter span (inches)