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 (3003 H14): 22.0×10^3psi = 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 ACP 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 ACP 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 ACP occur?

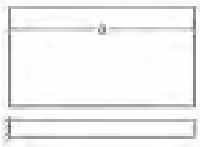
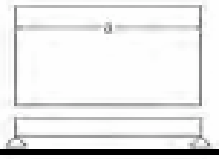
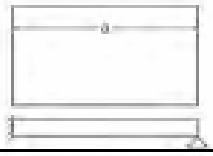
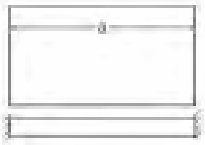
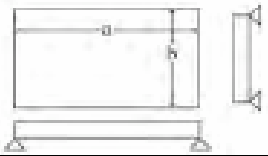
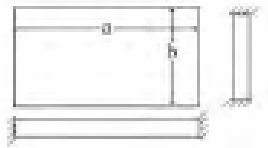
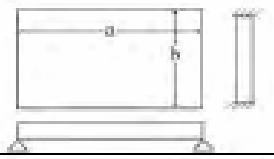
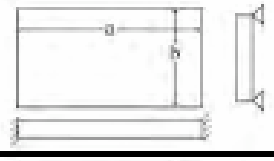
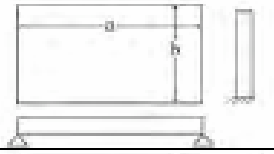
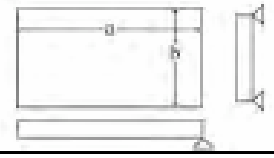
According to Table 11-1, case No. 6 a/b=1. Therefore β=0.3078.

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

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

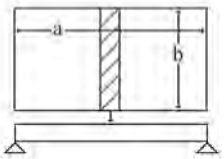
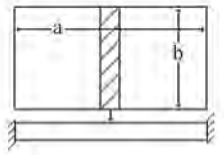
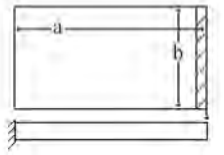
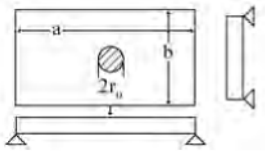
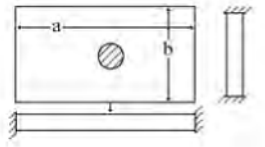
Therefore, 3mm thick ACP panel is all right in this case.

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

No.	Support Condition	Conditions Illustrated	Maximum Skin Stress (σ_{MAX}) Formula
1	1 side fixed, 3 sides free		$\sigma_{MAX} = \frac{3wa^2}{t^2}$
2	2 sides simply supported, 2 sides free		$\sigma_{MAX} = \frac{3}{4} \cdot \frac{wa^2}{t^2}$
3	1 side fixed opposite side simply supported, 2 sides free		$\sigma_{MAX} = \frac{3}{4} \cdot \frac{wa^2}{t^2}$
4	2 sides fixed, 2 sides free		$\sigma_{MAX} = \frac{1}{2} \cdot \frac{wa^2}{t^2}$
5	4 sides simply supported		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.2 / 1.4 / 1.6 / 1.8 / 2.0 / 3.0 β: 0.2874 / 0.3762 / 0.4530 / 0.5172 / 0.5688 / 0.6102 / 0.7134
6	4 sides fixed		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.2 / 1.4 / 1.6 / 1.8 / 2.0 / ∞ β: 0.3078 / 0.3834 / 0.4356 / 0.4680 / 0.4872 / 0.4974 / 0.500
7	Longer sides fixed, shorter sides simply supported		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.2 / 1.4 / 1.6 / 1.8 / 2.0 / ∞ β: 0.4182 / 0.4086 / 0.4860 / 0.4968 / 0.4971 / 0.4973 / 0.500
8	Longer sides simply supported, shorter sides fixed		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.2 / 1.4 / 1.6 / 1.8 / 2.0 / ∞ β: 0.4182 / 0.5208 / 0.5988 / 0.6540 / 0.6912 / 0.7146 / 0.750
9	1 longer side fixed, another longer side free, shorter sides simply supported		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.5 / 2 / 3 / ∞ β: 0.714 / 1.362 / 1.914 / 2.568 / 3.00
10	1 shorter side free, other sides simply supported		$\sigma_{MAX} = \beta \cdot \frac{wb^2}{t^2}$ a/b: 1 / 1.5 / 2 / 4 β: 087 / 077 / 079 / 080

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

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

No.	Support Condition	Conditions Illustrated	Maximum Skin Stress (σ_{MAX}) Formula
1	2 sides simply supported, 2 sides free, center load		$\sigma_{MAX} = \frac{3}{2} \cdot \frac{Wa}{bt^2}$
2	2 sides fixed, 2 sides free, center load		$\sigma_{MAX} = \frac{3}{4} \cdot \frac{Wa}{bt^2}$
3	1 side fixed, other sides free, tip load		$\sigma_{MAX} = 6 \cdot \frac{Wa}{bt^2}$
4	4 sides simply supported, concentrated center load		$\sigma_{MAX} = 0.145 \frac{W}{t^2} \left[4.3 \log \frac{2b}{\pi r_0} + 1 - 3.3\beta \right]$
5	4 sides fixed, concentrated center load		$\sigma_{MAX} = \beta \cdot \frac{W}{t^2}$

a/b	1	1.2	1.4	1.6	1.8	2.0
β	0.565	0.350	0.211	0.125	0.073	0.072

a/b	1	1.2	1.4	1.6	1.8	2.0
β	0.7542	0.8940	0.9624	0.9906	1.000	1.004

(note) W: load (lbf)
longer span (inch)
shorter span (inch)

(2) Deflection Calculation

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

The deflection of ACP 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:

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

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

α: constant given by supporting conditions

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

t_{Ap}: ACP 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 $E_{Ap} \cdot t_{Ap}^3$

t_{Ap} (mm)	E_{Ap} (psi)	$E_{Ap} \cdot t_{Ap}^3$ (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)

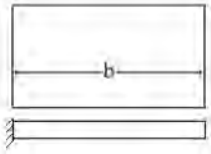
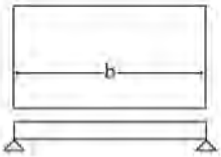
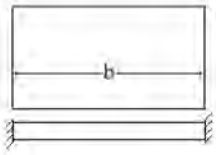
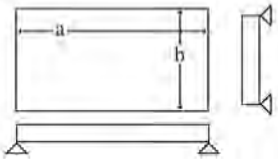
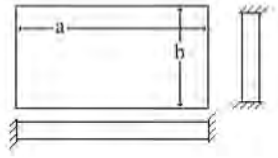
When ACP is 3mm thick, panel size being 3½' x 3½' square, supporting conditions being 4 sides fixed and wind load w=30 lbf/ft^2, how much does ACP deflect?

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

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

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

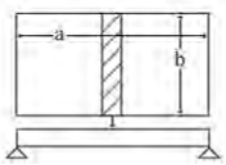
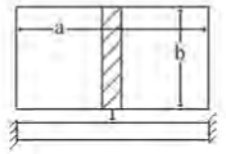
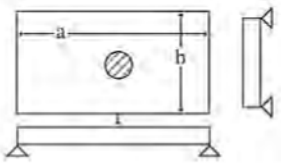
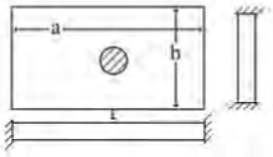
Table 11-5. Constants by supporting condition when the load is uniformly Distributed

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

(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		$\delta_{MAX} = 0.25 \cdot \frac{Wa^3}{bE_{Ap} \cdot t_{Ap}^3}$
2	2 sides fixed, 2 sides free, center load		$\delta_{MAX} = 0.0625 \cdot \frac{Wa^3}{bE_{Ap} \cdot t_{Ap}^3}$
3	4 sides simply supported, concentrated center load		$\delta_{MAX} = \alpha \cdot \frac{Wb^2}{E_{Ap} \cdot t_{Ap}^3}$ 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		$\delta_{MAX} = \alpha \cdot \frac{Wb^2}{E_{Ap} \cdot t_{Ap}^3}$ 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 ACP (psi)
t_{Ap}:	ACP thickness (mm)
W:	concentration load (lbf)
a:	larger span (inches)
b:	shorter span (inches)