Appendix
Zinc Composite Material (ZCM) – Series of ALPOLIC® –

1. Surface characteristics of zinc alloy

(1) Composition of zinc allopy
Zinc: 99.5% or more, copper: 0.2%, titanium: 0.1%

(2) Surface finish
Zinc alloy is initially finished with a chemical conversion layer of Silver Light Gray, formed in the production line. This initial layer will be replaced with a naturally produced protective layer through natural weathering.

(3) Excellent durability
Zinc alloy forms corrosion-resistant layer (zinc carbonate) on its surface under natural atmospheric conditions. Protected with the layer, zinc's erosion rate is only 1-7 microns per year (3 microns in average), which indicates that 100 microns (0.1mm) thick zinc lasts as long as 35 years to erode.

(4) Color change through weathering
A protective layer naturally emerges on the surface, and after several years of natural weathering, the zinc surface reaches a stable natural layer. The natural layer's main component is zinc carbonate, but small contents of other zinc compounds may coexist in the layer, and hence the color can take different tints depending on the atmospheric conditions. This transition takes place so slowly that the color change is almost imperceptible from its appearance.

(5) Self-repairing of scratch
As the naturally produced layer can heal scratches, surface scratches become invisible through natural weathering.

2. Comparison of properties of metals

The following table shows typical values of principal properties of zinc metal in comparison with other metals.

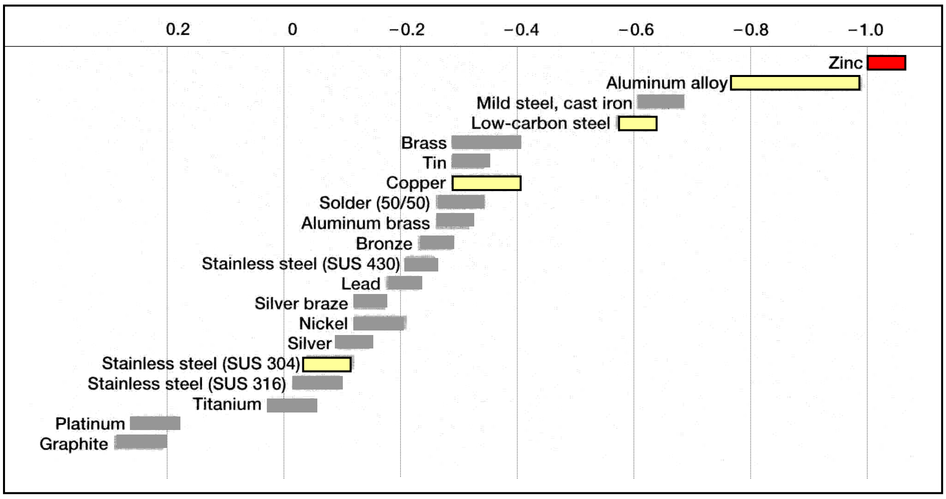
	Unit	Zinc alloy	Aluminum	Galvanized steel	Stainless steel 304	Copper
Specific gravity		7.1	2.7	7.9	7.9	8.9
Melting point	°C °F	420 790	650 1200	1530 2790	1400 2550	1080 1980
Thermal expansion/ contraction ratio	10^{-6} mm/mm/°C	(P) 22-24x10^{-6} (T) 18-19x10^{-6}	24	12	17	17
	10^{-6} in/in/°F	(P) 12-13x10^{-6} (T) 10-11x10^{-6}	13	6.7	9.5	9.5
Thermal conductivity	m^2.hr.°C/kcal m^2.°K/W	97 113	180 210	46 54	14 16	331 385
Tensile strength	MPa, N/mm^2	(P) 240 (T) 170	152	340	580	245
	10^3 psi	(P) 35 (T) 25	22	49	84	36
Modulus of elasticity	10^3 MPa,N/mm^2	(P) 110 (T) 87	70	210	200	120
	10^6 psi	(P) 16 (T) 13	10	30	29	17
Hardness	Hv	40-60	75	100	150	75

Note: The thermal expansion/contraction and mechanical properties of zinc is different between directions. In the table, P and T indicate "Parallel to Rolling Direction" and "Traverse to Rolling Direction" respectively.

3. Galvanic potential

Zinc's corrosion potential is lower than other metals. Contact with steel and copper, of which corrosion potential is higher, may cause an accelerated corrosion of zinc under moist conditions. Aluminum and stainless steel form inactive layers on the surface and will not cause such an accelerated corrosion of zinc.

Corrosion potential in seawater (flowing water)



4. Thermal expansion/contraction

ZCM's expansion/contraction coefficient is almost the same as aluminum metal and nearly twice of steel and concrete. The following table shows the expansion/contraction of various building materials.

	Unit	ZCM Z-Z	ZCM Z-A	ALPOLIC/fr	Aluminum	Steel
Thermal expansion / contraction coefficient	10^{-6} mm/mm/°C	(P) 28 (T) 20	(P) 25 (T) 22	24	24	12
	10^{-6} in/in/°F	(P) 15 (T) 11	(P) 14 (T) 12	13	13	6.7
Expansion per 1 meter with 50°C change	mm	(P) 1.4 (T) 1.0	(P) 1.3 (T) 1.1	1.2	1.2	0.6
Expansion per 3 ft with 90°F change	inch	(P) 0.049" (T) 0.036"	(P) 0.042" (T) 0.036"	0.042"	0.042"	0.022"

(Continued)

	Unit	Stainless steel 304	Copper	Concrete	Glass	Acrylic sheet
Thermal expansion / contraction coefficient	10^{-6}mm/mm/°C 10^{-6}/in/in/°F	17 9.5	17 9.5	12 6.7	9 5.0	70 39
Expansion per 1 meter with 50°C change	mm	0.9	0.9	0.6	0.5	3.5
Expansion per 3 ft with 90°F change	inch	0.031"	0.031"	0.022"	0.016"	0.13"

Note: In the table, P and T indicate "parallel to rolling direction" and "traverse to rolling direction" respectively.

5. Rigidity and panel weight

The following table shows the rigidity of ZCM in comparison with other metals. ZCM is highly rigid and light in weight. ZCM is equivalent to 2.9 mm thick solid zinc sheet and 3.1 mm thick aluminum sheet in rigidity.

Rigidity of ZCM and other metals

	Unit	ZCM Z-Z	ZCM Z-A	Zinc alloy	Aluminum	Steel	Stainless steel 304
Thickness of equivalent rigidity	mm	4	4	2.92	3.14	2.18	2.21
Modulus of elasticity (E)	10^3 N/mm^2 (10^6 psi)	33 Note (4.8)	34 Note (4.9)	87 (13)	70 (10)	210 (30)	200 (29)
Flexural rigidity (E×I)	kNmm^2/mm (10^3 lbs.in^2/in)	180 Note (1.6)	180 Note (1.6)	181 (1.6)	181 (1.6)	181 (1.6)	180 (1.6)
Panel weight	kg/m^2 (psf)	10.8 (2.21)	9.3 (1.91)	20.7 (4.24)	8.5 (1.74)	17.2 (3.53)	17.5 (3.59)
Weight ratio	%, ZCM Z-Z=100 %, ZCM Z-A=100	100 -	- 100	192 223	79 91	159 185	162 188

Note: We will use the same (safer) value for both ZCM Z-Z and Z-A for our structural calculations, because the difference between two grades is negligibly small.

Comparison between ZCM and ALPOLIC/fr 4mm

	Unit	ZCM 4mm	ALPOLIC/fr 4mm
Modulus of elasticity (E)	10^3 N/mm^2 (10^6 psi)	33 (4.8)	40 (5.8)
Flexural rigidity (E×I)	kNmm^2/mm (10^3 lbs.in^2/in)	180 (1.6)	210 (1.9)
Aluminum thickness of equivalent rigidity	mm	3.14	3.30
Panel weight	kg/m^2 psf	9.3-10.8 1.91-2.21	7.6 1.56

6. Panel strength

When wind load works on ZCM panels, a certain intensity of stress will arise in metal skin to withstand the bending force. At the same time, the panel will show a certain deflection. If the intensity of stress is larger than the permissible limit, ZCM panel will lose its elasticity and the deflection will not be restored. We can check this possibility with the following calculations.

(1) Calculation of stress

A. Calculation method

We calculate the max stress that may arise in metal skins of ZCM when a wind load works on it. We can use the following equation for both ZCM Z-Z and Z-A. When the calculated max stress is lower than 0.2% proof stress of zinc skin (168 MPa or N/mm^2 (or 24×10^3 psi)), we can say that the ZCM will withstand the condition. A suitable safety factor shall be involved.

$$\text{Stress} = B \cdot w \cdot b^2 / t^2$$

Where, Stress: in MPa or N/mm^2 (or psi), b: Panel width in mm (or inch)
B: Coefficient, as shown in Reference 1 below, w: Wind pressure in MPa or N/mm^2 (or psi)
t^2: Square of apparent thickness of ZCM, given as 7.81 mm^2 (or 12.1×10^{-3} in^2)

B. Calculation results of typical cases

Table 1 and 2 show the calculated results of 4-side simply supported and 4-side fixed cases respectively.

(2) Calculation of deflection

A. Calculation method

We can calculate the max deflection of ZCM panel with the following equation.

Deflection = $A \cdot w \cdot b^4 / E_{AP} t_{AP}^3$

Where, Deflection: in mm (or inch), b: Panel width or height, whichever the shorter, in mm (or inch)
A: Coefficient, as shown in Reference 2 below, w: Wind pressure in MPa or N/mm^2 (or psi)
$E_{AP:}$ Flexural elastic modulus of ZCM, t_{AP}: Thickness of ZCM in mm (or inch)
$E_{AP}t_{AP}^3$ value is given as 2110×10^3 N·mm (or 18.8×10^3 lbs·inch)

B. Calculation result of typical cases

Table 3 and 4 show the calculated results of 4-side simply supported and 4-side fixed cases respectively.

Table 1, Stress (Supporting condition: 4-side simply supported) (N/mm^2)

w, kPa (kg/m^2)	**b**, Panel width (mm)	**a**, Panel length (mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
(1.0 (102)	600	22	28	31	33	35	35	35	35	35
	750	27	37	41	47	50	54	54	54	54
	900	30	44	56	63	67	71	74	78	78
2.0 (204)	600	45	56	61	66	69	69	69	69	69
	750	54	75	82	94	100	108	108	108	108
	900	60	88	111	127	134	141	148	156	156
3.0 (306)	600	67	84	92	99	104	104	104	104	104
	750	81	112	123	141	150	162	162	162	162
	900	89	133	167	190 >	201 >	211 >	222 >	233 >	233 >

Table 2, Stress (Supporting condition: 4-Side Fixed) (N/mm^2)

w, kPa (kg/m^2)	**b**, Panel width (mm)	**a**, Panel length (mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
(1.0 (102)	600	21	23	23	23	23	23	23	23	23
	750	28	34	36	36	36	36	36	36	36
	900	32	43	49	52	52	52	52	52	52
2.0 (204)	600	42	46	46	46	46	46	46	46	46
	750	55	67	72	72	72	72	72	72	72
	900	64	87	99	103	104	104	104	104	104
3.0 (306)	600	63	69	69	69	69	69	69	69	69
	750	83	101	108	108	108	108	108	108	108
	900	96	130	148	155	156	156	156	156	156

How to read the table: "**>**" indicates that the maximum stress is larger than 0.2% proof stress (yield stress) of zinc skin (168 MPa or N/mm^2). Therefore, stiffener will be required in this range. In other range where the calculated stress is lower than 168 MPa or N/mm^2, the ZCM panel will withstand the wind load without stiffener.

Table 3, Deflection (Supporting condition: 4-side simply supported) (mm)

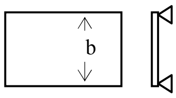
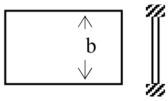
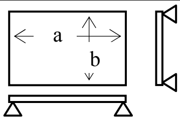
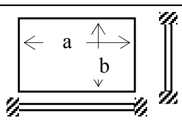
w, kPa (kg/m^2)	**b**, Panel width (mm)	**a**, Panel length (mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
(1.0 (102)	600	5	7	8	8	9	9	9	9	9
	750	9	14	17	18	19	21	21	21	21
	900	14	22	29	35	37	39	42	44	44
2.0 (204)	600	10	14	15	16	18	18	18	18	18
	750	19	27	33	36	39	43	43	43	43
	900	27	45	59	69	73	78	83	88	88
3.0 (306)	600	15	20	23	25	26	26	26	26	26
	750	28	41	50	54	58	64	64	64	64
	900	41	67	88	**NA >**	**NA >**	**NA >**	**NA >**	**NA >**	**NA >**

Note: "**NA**" indicates that the ZCM panel shows a permanent deformation under this condition.

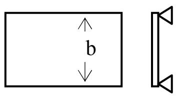
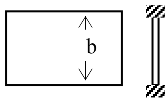
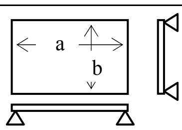
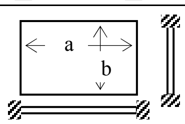
Table 4, Deflection (Supporting condition: 4-side fixed) (mm)

w, kPa (kg/m2)	**b,** Panel width (mm)	**a,** Panel length (mm)								
		900	1200	1500	1800	2100	2400	2700	3000	>3000
(1.0 (102)	600	2	2	2	2	2	2	2	2	2
	750	3	4	4	4	4	4	4	4	4
	900	4	7	8	9	9	9	9	9	9
2.0 (204)	600	3	3	4	4	4	4	4	4	4
	750	6	8	8	9	9	9	9	9	9
	900	9	13	16	17	18	18	18	18	18
3.0 (306)	600	4	5	5	5	5	5	5	5	5
	750	8	11	12	13	13	13	13	13	13
	900	13	20	24	26	27	27	27	27	27

Reference 1, Coefficient B for calculation of stress

<table>
<tr><td>Supporting condition</td><td></td><td colspan="9">Equation and B value</td></tr>
<tr><td>2-side simply supported and 2-side free</td><td></td><td colspan="9">$Stress_M = 0.75 \cdot w \cdot b^2 / t^2$</td></tr>
<tr><td>2-side fixed and 2-side free</td><td></td><td colspan="9">$Stress_M = 0.5 \cdot w \cdot b^2 / t^2$</td></tr>
<tr><td rowspan="3">4-side simply supported</td><td rowspan="3"></td><td colspan="9">$Stress_M = B \cdot w \cdot b^2 / t^2$</td></tr>
<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><td>>3.0</td></tr>
<tr><td>B</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><td>0.75</td></tr>
<tr><td rowspan="3">4-side fixed</td><td rowspan="3"></td><td colspan="9">$Stress_M = B \cdot w \cdot b^2 / t^2$</td></tr>
<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>>2.0</td><td></td></tr>
<tr><td>B</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>0.5000</td><td></td></tr>
</table>

Reference 2, Coefficient A for calculation of deflection

<table>
<tr><td>Support condition</td><td></td><td colspan="9">Equation and A value</td></tr>
<tr><td>2-side simply supported and 2-side free</td><td></td><td colspan="9">$Deflection = 0.156 \cdot w \cdot b^4 / (E_{AP} . t_{AP}^3)$</td></tr>
<tr><td>2-side fixed and 2-side free</td><td></td><td colspan="9">$Deflection = 0.0313 \cdot w \cdot b^4 / (E_{AP} . t_{AP}^3)$</td></tr>
<tr><td rowspan="3">4-side simply supported</td><td rowspan="3"></td><td colspan="9">$Deflection = A \cdot w \cdot b^4 / (E_{AP} . t_{AP}^3)$</td></tr>
<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><td>>3.0</td></tr>
<tr><td>A</td><td>0.044</td><td>0.062</td><td>0.077</td><td>0.0906</td><td>0.1017</td><td>0.1110</td><td>0.1335</td><td>0.1422</td></tr>
<tr><td rowspan="3">4-side fixed</td><td rowspan="3"></td><td colspan="9">$Deflection = A \cdot w \cdot b^4 / (E_{AP} . t_{AP}^3)$</td></tr>
<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>>2.0</td><td></td></tr>
<tr><td>A</td><td>0.0138</td><td>0.0188</td><td>0.0226</td><td>0.0251</td><td>0.0267</td><td>0.0277</td><td>0.0284</td><td></td></tr>
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