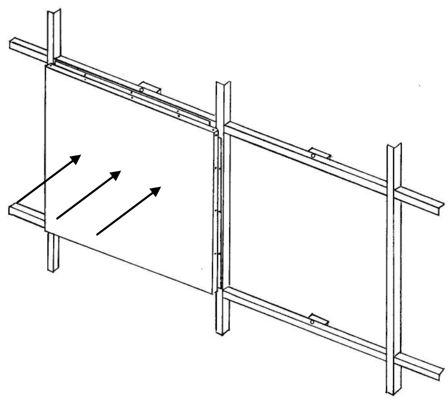
Guidance for Designing

Guidance for Designing

One of the most important works throughout ALPOLIC®/fr work is to complete the shop drawing in conformity with the architectural drawings and the requirements peculiar to the project. In order to complete the shop drawing, we have to consult well about the panel layout, installation details and so on with the architect and the client. At the same time, we have to verify that the installation method totally conforms to the project specifications. On most ALPOLIC®/fr projects, the following items will be studied as fundamentals of the design:

1. Structural strength
2. Thermal expansion
3. Thermal insulation
4. Waterproofing
5. Panel layout and special panel detail

We will look over these items in this section.



1. Structural strength

Whenever ALPOLIC®/fr panels are used outdoors, the panels and the sub-structure must withstand outdoor wind load. When wind blows toward panels, the panels and the sub-structure will be pushed with positive pressure, and accordingly deflection will occur. If the deflection is small enough and is within the elasticity range, the panels and the sub-structure will be restored to the original position when the wind load is eliminated.

ALPOLIC®/fr panels on the opposite side of the building, on the contrary, will be pulled with suction (negative) pressure, and a tension will occur in junction points. In the event that the pulling load is extremely large, the junction may be torn off.

Thus, we have to study overall structural strength of the installation system, based on the design wind load specified for the project.

1-1. Strength of ALPOLIC®/fr panel

Calculation of permanent deformation: The strength of ALPOLIC®/fr panels comes from its aluminum skins. Namely, if the stress exerted in aluminum skins is smaller than the permissible range, permanent deformation will not occur. In this evaluation, the permissible range is given as 0.2% proof stress (or yield stress) of aluminum skin divided by a safety factor. 0.2% proof stress depends on aluminum alloy and tempering condition, and the following values are used for ALPOLIC®/fr:

ALPOLIC®/fr	Alloy and tempering	0.2% proof stress
3mm, 4mm and 6mm	3105 H14	152 N/mm^2

Generally, panel strength depends on the following factors:

(1) Wind load
(2) Supporting condition
(3) ALPOLIC®/fr thickness

(4) Aluminum skin thickness and 0.2% proof stress
(5) ALPOLIC®/fr panel size

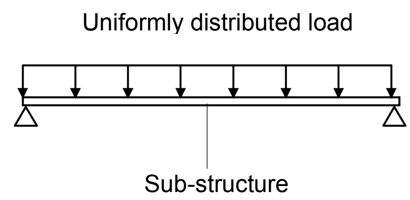
The panel strength can be calculated with the above factors and with several equations, as detailed in White Binder (Technical Brochure of ALPOLIC®).

Calculation of panel deflection: Permanent deformation is an ultimate condition and it is indispensable. Panel deflection, on the other hand, belongs to serviceability conditions of the project. If the maximum deflection is specified in the project requirements, we have to confirm whether the expected deflection conforms to the project specifications or not. The calculation method of deflection is also detailed in White Binder (Technical Brochure of ALPOLIC®).

The calculated results for 3mm, 4mm and 6mm are attached in **Appendix 1**. The structural calculation method is outlined in **Appendix 2**.

1-2. Deforming due to shearing force
In those areas where earthquake is possible to hit, the external cladding panel must withstand the shearing force across the panel surface. Appendix 3 is a test result in accordance with JIS A1414 “Deforming test of non-bearing wall panel due to shearing force parallel to panel surface.” As shown in this test, ALPOLIC®/fr panel withstands the shearing force in the displacement range from 1/400 to 1/50.

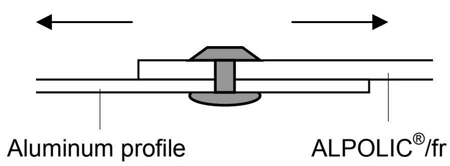
1-3. Strength of sub-structure
Normally, ALPOLIC®/fr panels are installed on sub-structure made of steel or aluminum. The sub-structure also must withstand the wind load. The strength of sub-structure depends on the following factors:



(1) Rigidity of sub-structure
(2) Supporting (anchoring) interval of sub-structure
(3) Wind pressure loading on sub-structure

As sub-structure is normally deemed as a part of structure, the maximum deflection must meet L/200 rule: the maximum deflection must be smaller than the supporting interval divided by 200 (0.5% of supporting interval). Refer to **Appendix 3** for calculation example of sub-structure strength.

1-4. Strength of junction point
When suction pressure loads on ALPOLIC®/fr panel, the junction hole of rivet or screw must withstand the tension. Otherwise, the junction hole will be torn off and the panel will be removed. **Appendix 4** shows how to evaluate the strength of junction hole. Based on this method, the junction interval can be determined.



In actual installation work, the position of junction hole is important. When the hole is positioned in the proximity of panel edge, its strength will be lessened and may be unsatisfactory. Normally, the distance from hole center to panel edge should be larger than twice of hole diameter. Refer to

Appendix 4 for further detail.

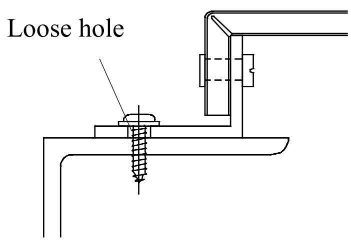
Note: In order to prevent from galvanic corrosion of ALPOLIC®/fr, use aluminum or stainless steel rivet, bolt or screw for joining. When ALPOLIC®/fr is connected to different metal, lay a coating film 25 microns or thicker on the metal.

2. Thermal expansion

The thermal expansion ratio of ALPOLIC®/fr is the same as aluminum. Therefore, temperature change will not cause a movement between ALPOLIC®/fr and aluminum extrusions. However, because thermal expansion of steel and concrete is smaller, a certain extent of movement is anticipated in long panel between ALPOLIC®/fr panels and these structural materials. This movement is normally as small as 1-3mm, but it must be relieved with a suitable method.

Thermal expansion & contraction

Material	Expansion ratio (/°C)	Elongation per 1m per 50°C
ALPOLIC®/fr	24×10^{-6}	1.2mm
Aluminum	24×10^{-6}	1.2mm
Steel	12×10^{-6}	0.6mm
Concrete	12×10^{-6}	0.6mm
Acrylic sheet	$50\text{-}90\times10^{-6}$	2.5-4.5mm



Acrylic sheet, on the contrary, has a larger expansion rate. When acrylic sheet is adhered on ALPOLIC® panel, the adhesion must permit some movement of acrylic sheet.

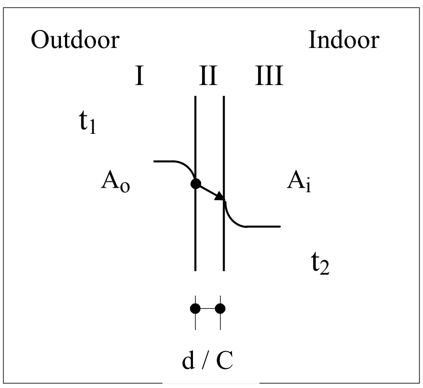
The drawing indicates an example of loose hole to relieve a possible movement between ALPOLIC®/fr panel and sub-structure made of steel.

3. Thermal insulation

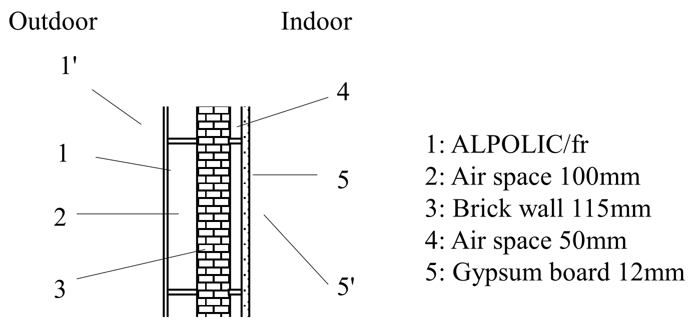
When ALPOLIC®/fr is used for external wall cover, the thermal insulation of overall wall system will be evaluated.

The heat transmits by three mechanisms of radiation, convection and conduction. The heat transmission dealt with external wall is a sum composed of these mechanisms. When temperature difference exists between outdoor and indoor atmosphere, the heat flows from the higher temperature to the lower temperature, through the heat transfer from air to wall (I), heat conduction inside the wall (II) and heat transfer from wall to air (III). The overall heat flow process is called heat transmission and expressed with K-value (kcal/m^{2}h°C) or U-value (W/(m^{2}K).

Heat Transmission



The heat transmission through overall wall system is a sum of each component of wall materials from the outer surface of ALPOLIC®/fr to the inner surface of interior. Generally speaking, ALPOLIC®/fr panel itself does not have a sufficient thermal insulation effect as an external wall, but the air space between ALPOLIC®/fr panel and wall material has a recognizable insulation effect. The following table is an example of calculation of total heat transmission.



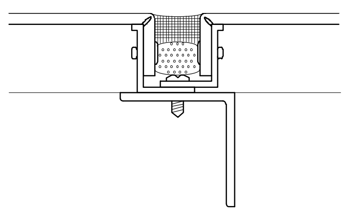
Example of calculated heat transmission through external wall

No	Component of heat flow	Equation	Value, $kcal/m^2h°C$
1'	Heat transfer from outer air to ALPOLIC®	$1/A_o$	0.05
1	Internal heat conduction in ALPOLIC®	d_1/C_1	0.004/0.39=0.01
2	Internal heat transfer in air space	d_2/C_2	0.10
3	Internal heat conduction in brick wall	d_3/C_3	0.115/0.24=0.48
4	Internal heat transfer in air space	d_4/C_4	0.10
5	Internal heat conduction in gypsum board	d_5/C_5	0.012/0.11=0.11
5'	Heat transfer from gypsum board to inner air	$1/A_I$	0.13
	Total	$1/K=1/A_o+\Sigma d_i/C_i+1/A_i$	1/K=0.98 K=1.02 $kcal/m^2h°C$ (U=1.19 $W/(m^2K)$

K-value: Heat transmission ($kcal/m^2h$)
$A_{o,i}$: Heat transfer coefficients ($kcal/m^2h°C$)
C: Heat conductivity (kcal/mh°C)
d: Wall thickness (m)
Note: K-value is also called U-value in SI unit in ISO, and converted by K-value ($kcal/m^2h$)=0.86×U-value ($W/(m^2K)$).
Refer to **Appendix 5** for further details.

4. Waterproofing

In order to ensure waterproofing of joints between panels, normally, a sealing material is used for joints. The sealing material shall meet the performance required for the project and also it must be compatible with ALPOLIC®/fr panel. Silicone, modified silicone, polysulfide and polyurethane sealant are used for exterior. Among these materials, silicone sealant is the best in weatherability, but, as widely known, it stains panel surface. Recently, sealant manufacturers developed less staining type of silicone, in which the disadvantage of staining is considerably improved. Refer to **Appendix 6** for general comparison among sealing materials. Regarding the joint design such as joint width and thickness, please follow the sealant manufacturer's specifications.



Actual sealing work at site is also important. Improper work will affect not only the aesthetic appearance of installed panel but also the waterproofing performance of the joint. Therefore, the sealing work must be conducted carefully, based on the instructions from sealant manufacturers. For the typical sealing procedures, refer to **Fabrication and Installation**.

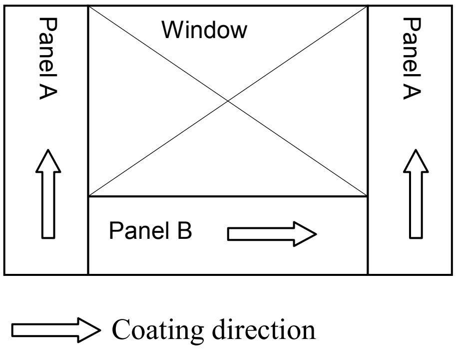
When rubber gasket is used for joint, the waterproofing will not be perfect, taking its long-term durability into consideration. Therefore, a secondary-waterproofing device may be provided behind joint to ensure the perfect waterproofing.

5. Panel layout and special panel detail

(1) Coating direction of Metallic Colors and Sparkling Colors

In case of Metallic Colors and Sparkling Colors, there is a slight color difference between standing vertically (like portrait) and horizontally (like landscape) due to the coating direction. This slight color difference is subtle but perceptible from some angle after installation. Therefore, in case of traverse and parallel coating directions are co-existing in an area, the color difference must be carefully checked in advance.

In the shown example, it is likely that the color difference between Panel A and B is perceptible from some angle in case of Metallic and Sparkling Colors.



Stone Series requires the similar attention, because it consists of small grain pattern with directional arrangement. The similar check is necessary for Stone Series in advance.

In case of Solid Colors (No-metallic Colors), the above color difference is negligible. Solid Color panels can be laid out with different coating direction. It is because of the smoother and the finer coating of ALPOLIC®/fr derived from Die Coating.

(2) Bending limit

There are two types of bending methods: by press brake and by 3-roll bender. By means of press brake, the minimum bendable limit of ALPOLIC®/fr is about 80-100 mm in radius. By means of 3-roll bender, it is 250 to 300 mm in radius, depending on the diameter of the bending roll. Please refer to **Fabrication and Installation** for details.

(3) Special panel detail

Special shaped panels such as 3-dimension panels and combined panels are often required. Whenever we face to such complicated panels, we have to study how to embody the shape without degrading the advantages of ALPOLIC®/fr. Sometimes we have to ask some modification on the original design for compromise. Several types of these panels are shown in **Fabrication and Installation**.

6. Lightning

In the event that a lightning should strike ALPOLIC®/fr panel instead of lightning rod, what will happen on the panel and the building. When the aluminum skin is connected to the ground earth, the electricity will be discharged to the ground earth and nothing will happen in the vicinity of the struck panel, although the struck panel itself might be damaged with the enormous magnitude of lightning impact. Refer to **Appendix 7** for further details.

Structural strength of ALPOLIC®/fr

The maximum stress exerting in aluminium skin of ALPOLIC/fr can be calculated with the following equation:

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

Where, b: panel width or height, whichever shorter side
B: coefficient dependent on a/b ratio (panel width/panel height) and supporting condition, as shown in White Binder P. 10.
w: wind pressure (N/mm^2 or $10^{-6} \times N/m^2$ or $10^{-3} \times kPa$)
t^2: square of apparent thickness of ALPOLIC®, given in the following table:

The relevant values to ALPOLIC®/fr 3mm, 4mm and 6mm are given as follows:

ALPOLIC®/fr	t^2 (mm^2)	0.2% proof stress
3mm	6.33	152 N/ mm^2
4mm	9.25	152 N/ mm^2
6mm	15.17	152 N/ mm^2

When the maximum stress calculated with the above equation does not exceed 0.2% proof stress (yield stress), aluminium skins are still within elastic range and permanent deformation will not occur.
Note: Regarding details of the above calculation method, refer to White Binder, in which structural calculation methods are explained for general purpose.

The maximum deflection of ALPOLIC/fr panel, on the other hand, can be calculated with the following equation:

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

Where, b: panel width or height, whichever shorter side
A: coefficient dependent on a/b ratio (panel width/panel height) and supporting condition, as shown in White Binder P. 12.
w: wind pressure (N/mm^2 or $10^{-6} \times N/m^2$ or $10^{-3} \times kPa$)
E_{AP}: flexural elastic modulus of ALPOLIC/fr
t_{AP}: thickness of ALPOLIC/fr

$E_{AP} t_{AP}^3$ values are given as follows:

ALPOLIC®/fr	E_{AP} (N/mm^2)	$E_{AP} t_{AP}^3$ (N·mm)
3mm	49000	1323×10^3
4mm	39800	2546×10^3
6mm	29100	6287×10^3

Tables 1-6 are the calculated results for ALPOLIC/fr 3mm, 4mm and 6mm. The condition marked with ">" indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105-H14 (152 N/mm^2). Stiffener will be required in this condition. In other range, where the calculated stress is lower than 152 N/mm^2, the panel will withstand the condition without stiffener.

	ALPOLIC®/fr thickness	Supporting condition
Table 1	4mm	4-side fixed
Table 2	4mm	4-side simply supported
Table 3	6mm	4-side fixed
Table 4	6mm	4-side simply supported
Table 5	3mm	4-side fixed
Table 6	3mm	4-side simply supported

If you require other cases, which is not shown in the tables, please inquire to our office. We will provide separate calculation reports.

Table 1. ALPOLIC®/fr 4mm, 4-side fixed

Premise

Thickness:	ALPOLIC/fr 4mm
Supporting condition:	4-side fixed
Stiffener:	None

Maximum stress (N/mm^2)

w, kPa (kg/m^2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	18	19	19	19	19	19	19	19	19
	900	27	37	42	44	44	44	44	44	44
	1200	37	48	62	70	75	77	78	78	78
	1500	42	62	75	93	106	114	119	121	122
1.5 (153)	600	26	29	29	29	29	29	29	29	29
	900	40	55	62	65	66	66	66	66	66
	1200	55	72	93	106	113	116	117	117	117
	1500	62	93	112	140	159 >	171 >	178 >	181 >	182 >
2.0 (204)	600	35	39	39	39	39	39	39	39	39
	900	54	73	83	87	88	88	88	88	88
	1200	73	96	123	141	150	155 >	156 >	156 >	156 >
	1500	83	123	150	187 >	212 >	228 >	237 >	242 >	243 >
2.5 (255)	600	44	48	49	49	49	49	49	49	49
	900	67	91	104	109	109	109	109	109	109
	1200	91	120	154 >	176 >	188 >	194 >	195 >	195 >	195 >
	1500	104	154 >	187 >	233 >	265 >	285 >	296 >	302 >	304 >
3.0 (306)	600	53	58	58	58	58	58	58	58	58
	900	81	110	125	131	131	131	131	131	131
	1200	110	144	185 >	211 >	225 >	232 >	234 >	234 >	234 >
	1500	125	185 >	225 >	280 >	318 >	342 >	356 >	363 >	365 >

Note: “>” indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm^2). Stiffener will be required in this range.

Maximum deflection (mm)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	1	1	1	1	1	1	1	1	1
	900	4	5	7	7	7	7	7	7	7
	1200	6	11	16	19	21	23	23	23	23
	1500	7	16	27	37	45	50	53	55	56
1.5 (153)	600	2	2	2	2	2	2	2	2	2
	900	5	8	10	11	11	11	11	11	11
	1200	8	17	24	29	32	34	35	35	35
	1500	10	24	41	56	NA >	NA >	NA >	NA >	NA >
2.0 (204)	600	2	3	3	3	3	3	3	3	3
	900	7	11	13	14	15	15	15	15	15
	1200	11	22	32	39	43	NA >	NA >	NA >	NA >
	1500	13	32	55	NA >	NA >	NA >	NA >	NA >	NA >
2.5 (255)	600	3	4	4	4	4	4	4	4	4
	900	9	14	16	18	18	18	18	18	18
	1200	14	28	NA >	NA >	NA >	NA >	NA >	NA >	NA >
	1500	16	NA >	NA >	NA >	NA >	NA >	NA >	NA >	NA >
3.0 (306)	600	4	4	4	4	4	4	4	4	4
	900	11	16	20	21	22	22	22	22	22
	1200	17	34	NA >	NA >	NA >	NA >	NA >	NA >	NA >
	1500	20	NA >	NA >	NA >	NA >	NA >	NA >	NA >	NA >

Table 2. ALPOLIC®/fr 4mm, 4-side simply supported

Premise

Thickness:	ALPOLIC/fr 4mm
Supporting condition:	4-side simply supported
Stiffener:	None

Maximum stress (N/mm²)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	19	24	26	28	29	29	29	29	29
	900	25	37	47	53	56	59	62	66	66
	1200	37	45	62	76	87	95	99	103	117
	1500	47	62	70	92	110	126	138	148	182 >
1.5 (153)	600	28	36	39	42	44	44	44	44	44
	900	38	56	70	80	85	89	94	99	99
	1200	56	67	92	113	130	142	149	155 >	175 >
	1500	70	92	105	137	165 >	189 >	208 >	223 >	274 >
2.0 (204)	600	38	47	52	56	58	58	58	58	58
	900	50	75	94	107	113	119	125	131	131
	1200	75	89	123	151	173 >	190 >	198 >	206 >	234 >
	1500	94	123	140	183 >	220 >	252 >	277 >	297 >	365 >
2.5 (255)	600	47	59	64	69	73	73	73	73	73
	900	63	93	117	134	141	149	156 >	164 >	164 >
	1200	93	112	154 >	189 >	216 >	237 >	248 >	258 >	292 >
	1500	117	154 >	175 >	229 >	275 >	315 >	346 >	371 >	456 >
3.0 (306)	600	57	71	77	83	88	88	88	88	88
	900	76	112	141	160 >	169 >	178 >	187 >	197 >	197 >
	1200	112	134	185 >	227 >	260 >	285 >	297 >	309 >	350 >
	1500	141	185 >	210 >	275 >	331 >	377 >	415 >	445 >	547 >

Note: “>” indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm²). Stiffener will be required in this range.

Maximum deflection (mm)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	4	6	6	7	7	7	7	7	7
	900	11	19	24	29	31	32	34	37	37
	1200	18	36	54	68	81	90	95	100	109
	1500	24	54	87	123	153	180	202	221	NA >
1.5 (153)	600	6	8	9	10	11	11	11	11	11
	900	17	28	37	43	46	49	52	55	55
	1200	28	54	80	102	121	136	142	NA >	NA >
	1500	37	80	131	185	NA >	NA >	NA >	NA >	NA >
2.0 (204)	600	9	11	12	14	14	14	14	14	14
	900	23	37	49	57	61	65	69	73	73
	1200	37	72	107	137	NA >	NA >	NA >	NA >	NA >
	1500	49	107	175	NA >	NA >	NA >	NA >	NA >	NA >
2.5 (255)	600	11	14	16	17	18	18	18	18	18
	900	28	46	61	72	76	81	NA >	NA >	NA >
	1200	46	90	NA >	NA >	NA >	NA >	NA >	NA >	NA >
	1500	61	NA >	NA >	NA >	NA >	NA >	NA >	NA >	NA >
3.0 (306)	600	13	17	19	20	22	22	22	22	22
	900	34	56	73	NA >	NA >	NA >	NA >	NA >	NA >
	1200	55	108	NA >	NA >	NA >	NA >	NA >	NA >	NA >
	1500	73	NA >	NA >	NA >	NA >	NA >	NA >	NA >	NA >

Table 3. ALPOLIC®/fr 6mm, 4-side fixed

Premise

Thickness:	ALPOLIC/fr 6mm
Supporting condition:	4-side fixed
Stiffener:	None

Maximum stress (N/mm^2)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	11	12	12	12	12	12	12	12	12
	900	16	22	25	27	27	27	27	27	27
	1200	22	29	38	43	46	47	47	47	47
	1500	25	38	46	57	65	69	72	74	74
1.5 (153)	600	16	18	18	18	18	18	18	18	18
	900	25	33	38	40	40	40	40	40	40
	1200	33	44	56	64	69	71	71	71	71
	1500	38	56	68	85	97	104	108	111	111
2.0 (204)	600	21	24	24	24	24	24	24	24	24
	900	33	45	51	53	53	53	53	53	53
	1200	45	58	75	86	92	94	95	95	95
	1500	51	75	91	114	129	139	145	148	148
2.5 (255)	600	27	30	30	30	30	30	30	30	30
	900	41	56	63	66	67	67	67	67	67
	1200	56	73	94	107	114	118	119	119	119
	1500	63	94	114	142	162 >	174 >	181 >	184 >	185 >
3.0 (306)	600	32	35	36	36	36	36	36	36	36
	900	49	67	76	80	80	80	80	80	80
	1200	67	88	113	129	137	142	142	142	142
	1500	76	113	137	171 >	194 >	208 >	217 >	221 >	222 >

Note: “>” indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm^2). Stiffener will be required in this range.

Maximum deflection (mm)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	0	1	1	1	1	1	1	1	1
	900	1	2	3	3	3	3	3	3	3
	1200	2	5	7	8	9	9	9	9	9
	1500	3	7	11	15	18	20	21	22	23
1.5 (153)	600	1	1	1	1	1	1	1	1	1
	900	2	3	4	4	4	4	4	4	4
	1200	3	7	10	12	13	14	14	14	14
	1500	4	10	17	23	27	30	32	33	34
2.0 (204)	600	1	1	1	1	1	1	1	1	1
	900	3	4	5	6	6	6	6	6	6
	1200	4	9	13	16	17	18	19	19	19
	1500	5	13	22	30	36	40	43	45	46
2.5 (255)	600	1	1	1	1	1	1	1	1	1
	900	4	6	7	7	7	7	7	7	7
	1200	6	11	16	20	22	23	23	23	23
	1500	7	16	28	38	NA >	NA >	NA >	NA >	NA >
3.0 (306)	600	1	2	2	2	2	2	2	2	2
	900	4	7	8	9	9	9	9	9	9
	1200	7	14	20	24	26	27	28	28	28
	1500	8	20	33	NA >	NA >	NA >	NA >	NA >	NA >

Table 4. ALPOLIC®/fr 6mm, 4-side simply supported

Premise

Thickness:	ALPOLIC/fr 6mm
Supporting condition:	4-side simply supported
Stiffener:	None

Maximum stress (N/mm^2)

w, kPa	Panel width	Panel length (a, mm)								
(kg/m2)	(b, mm)	900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0	600	12	14	16	17	18	18	18	18	18
(102)	900	15	23	29	33	34	36	38	40	40
	1200	23	27	38	46	53	58	60	63	71
	1500	29	38	43	56	67	77	84	91	111
1.5	600	17	22	24	25	27	27	27	27	27
(153)	900	23	34	43	49	52	54	57	60	60
	1200	34	41	56	69	79	87	91	94	107
	1500	43	56	64	84	101	115	127	136	167 >
2.0	600	23	29	31	34	36	36	36	36	36
(204)	900	31	46	57	65	69	73	76	80	80
	1200	46	55	75	92	106	116	121	126	142
	1500	57	75	85	112	134	153 >	169 >	181 >	222 >
2.5	600	29	36	39	42	44	44	44	44	44
(255)	900	38	57	71	81	86	91	95	100	100
	1200	57	68	94	115	132	145	151	157 >	178 >
	1500	71	94	107	139	168 >	192 >	211 >	226 >	278 >
3.0	600	35	43	47	51	53	53	53	53	53
(306)	900	46	68	86	98	103	109	114	120	120
	1200	68	82	113	138	158 >	174 >	181 >	188 >	214 >
	1500	86	113	128	167 >	202 >	230 >	253 >	272 >	334 >

Note: ">" indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm^2). Stiffener will be required in this range.

Maximum deflection (mm)

w, kPa	Panel width	Panel length (a, mm)								
(kg/m2)	(b, mm)	900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0	600	2	2	3	3	3	3	3	3	3
(102)	900	5	7	10	12	12	13	14	15	15
	1200	7	15	22	28	33	37	38	40	44
	1500	10	22	35	50	62	73	82	89	107
1.5	600	3	3	4	4	4	4	4	4	4
(153)	900	7	11	15	17	19	20	21	22	22
	1200	11	22	33	41	49	55	58	61	66
	1500	15	33	53	75	93	109	123	134	NA >
2.0	600	3	5	5	6	6	6	6	6	6
(204)	900	9	15	20	23	25	26	28	30	30
	1200	15	29	43	55	65	73	77	81	88
	1500	20	43	71	100	124	NA >	NA >	NA >	NA >
2.5	600	4	6	6	7	7	7	7	7	7
(255)	900	11	19	25	29	31	33	35	37	37
	1200	19	36	54	69	82	92	96	NA >	NA >
	1500	25	54	89	125	NA >	NA >	NA >	NA >	NA >
3.0	600	5	7	8	8	9	9	9	9	9
(306)	900	14	22	30	35	37	39	42	45	45
	1200	22	44	65	83	NA >	NA >	NA >	NA >	NA >
	1500	30	65	106	NA >	NA >	NA >	NA >	NA >	NA >

Table 5. ALPOLIC®/fr 3mm, 4-side fixed

Premise

Thickness:	ALPOLIC/fr 3mm
Supporting condition:	4-side fixed
Stiffener:	None

Maximum stress (N/mm^2)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	26	28	28	28	28	28	28	28	28
	900	39	53	61	64	64	64	64	64	64
	1200	53	70	90	103	110	113	114	114	114
	1500	61	90	109	136	155 >	166 >	173 >	177 >	178 >
1.5 (153)	600	39	42	43	43	43	43	43	43	43
	900	59	80	91	95	96	96	96	96	96
	1200	80	105	135	154 >	165 >	170 >	171 >	171 >	171 >
	1500	91	135	164 >	204 >	232 >	250 >	260 >	265 >	267 >
2.0 (204)	600	51	57	57	57	57	57	57	57	57
	900	79	107	121	127	128	128	128	128	128
	1200	107	140	180 >	206 >	219 >	226 >	227 >	227 >	227 >
	1500	121	180 >	219 >	273 >	310 >	333 >	346 >	354 >	355 >

Note: “>” indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm^2). Stiffener will be required in this range.

Maximum deflection (mm)

w, kPa (kg/m2)	Panel width (b, mm)	Panel length (a, mm) 900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0 (102)	600	2	3	3	3	3	3	3	3	3
	900	7	11	13	14	14	14	14	14	14
	1200	11	22	31	37	41	43	45	45	45
	1500	13	31	53	72	NA >	NA >	NA >	NA >	NA >
1.5 (153)	600	4	4	4	4	4	4	4	4	4
	900	10	16	19	21	21	21	21	21	21
	1200	16	32	47	NA >	NA >	NA >	NA >	NA >	NA >
	1500	19	47	NA >	NA >	NA >	NA >	NA >	NA >	NA >
2.0 (204)	600	5	5	6	6	6	6	6	6	6
	900	14	21	25	27	28	28	28	28	28
	1200	21	43	NA >	NA >	NA >	NA >	NA >	NA >	NA >
	1500	25	NA >	NA >	NA >	NA >	NA >	NA >	NA >	NA >

Table 6. ALPOLIC®/fr 3mm, 4-side simply supported

Premise

Thickness:	ALPOLIC/fr 3mm
Supporting condition:	4-side simply supported
Stiffener:	None

Maximum stress (N/mm^2)

w, kPa	Panel width	Panel length (a, mm)								
(kg/m2)	(b, mm)	900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0	600	28	35	38	41	43	43	43	43	43
(102)	900	37	55	68	78	82	87	91	96	96
	1200	55	65	90	110	126	139	145	151	171 <
	1500	68	90	102	134	161 <	184 <	202 <	217 <	267 <
1.5	600	41	52	56	61	64	64	64	64	64
(153)	900	55	82	103	117	124	130	137	144	144
	1200	82	98	135	166 <	190 <	208 <	217 <	226 <	256 <
	1500	103	135	153 <	201 <	242 <	276 <	303 <	325 <	400 <
2.0	600	55	69	75	81	85	85	85	85	85
(204)	900	74	109	137	156 <	165 <	174 <	183 <	192 <	192 <
	1200	109	131	180 <	221 <	253 <	278 <	289 <	301 <	341 <
	1500	137	180 <	204 <	267 <	322 <	368 <	404 <	434 <	533 <

Note: ">" indicates that the maximum stress exceeds 0.2% proof stress (yield stress) of aluminum skin 3105 H14 (152 N/mm^2). Stiffener will be required in this range.

Maximum deflection (mm)

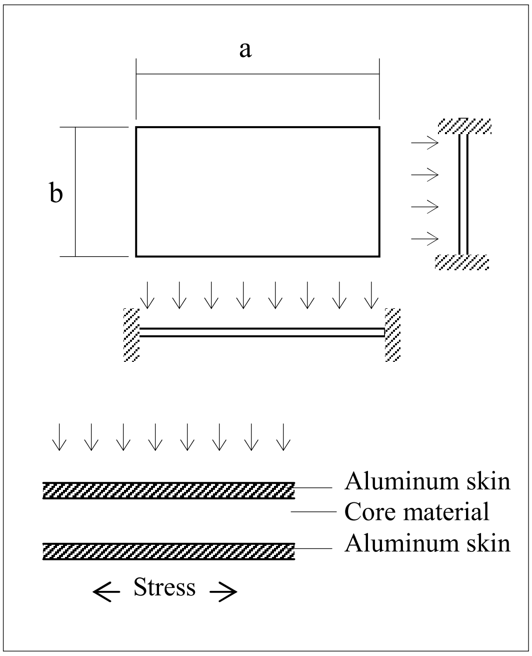
w, kPa	Panel width	Panel length (a, mm)								
(kg/m2)	(b, mm)	900	1200	1500	1800	2100	2400	2700	3000	>3000
1.0	600	8	11	12	13	14	14	14	14	14
(102)	900	22	36	47	55	59	63	66	71	71
	1200	36	69	103	131	155	174	183	192	209
	1500	47	103	168	237	NA <	NA <	NA <	NA <	NA <
1.5	600	12	16	18	20	21	21	21	21	21
(153)	900	33	53	70	83	88	94	99	106	106
	1200	53	103	155	NA <	NA <	NA <	NA <	NA <	NA <
	1500	70	155	NA <	NA <	NA <	NA <	NA <	NA <	NA <
2.0	600	16	22	24	26	28	28	28	28	28
(204)	900	44	71	94	NA <	NA <	NA <	NA <	NA <	NA <
	1200	71	138	NA <	NA <	NA <	NA <	NA <	NA <	NA <
	1500	94	NA <	NA <	NA <	NA <	NA <	NA <	NA <	NA <

Structural calculation method of ALPOLIC®/fr panel

1. Structural calculation without stiffener

(1) How to calculate the maximum stress

When wind pressure is working on ALPOLIC/fr panel, the panel shows some deflection. Simultaneously, some intensity of stress arises in the panel in order to withstand the bending force.



Strength design of ALPOLIC/fr assumes that bending strength of ALPOLIC/fr panel totally depends on aluminium skins. As far as the stress exerting in aluminium skin is lower than the permissible stress (0.2% proof stress or yield stress) of aluminum skin, the panel is still elastic. Therefore, we confirm whether the stress is lower or larger than the permissible stress.

This can be expressed with the following equation:

$Stress_M < Stress_Y$

Where,

$Stress_M$: Maximum stress in aluminum skin (N/mm^2 or kg/mm^2)

$Stress_Y$: 0.2% proof stress (yield stress) of aluminum skin (N/mm^2 or kg/mm^2)

The 0.2% proof stress (yield stress) depends on aluminum material and its tempering condition. In case of ALPOLIC (3105 H14), the following value is used:

$Stress_Y$ =152 Ng/mm^2 (=15.5 kg/mm^2)

The maximum stress exerting in aluminium sheet, depending on the support condition and panel size, can be calculated with the following equation:

$Stress_M = B \cdot w \cdot b^2 / t^2$

Where,

b: Panel width or height, whichever shorter side

B: Coefficient dependent on a/b ratio (panel width/panel height)

w: Wind pressure (kPa, kN/m^2 or kg/m^2)

t^2: Square of apparent thickness of ALPOLIC/fr, given in the following table:

ALPOLIC/fr	t^2 (mm^2)
3 mm	6.33
4 mm	9.25
6 mm	15.17

(2) Calculation example of maximum stress

A. Premise

Wind load: 1.5 kPa (1.5 kN/m^2 = 153 kg/m^2)
ALPOLIC/fr thickness: 4 mm
Panel size: 1220×2440 mm
Supporting condition: 4-side fixed

B. Result

$Stress_M = B \cdot w \cdot b^2 / t^2$

Where, a/b=2.0, then B=0.4974 (from Table 1 or White Binder P.10)

$Stress_M = 0.4974 \times 1500 \times 10^{-6} \times 1220^2 / 9.25$

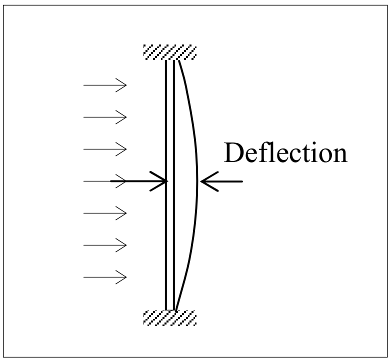
$= 120 < 152\ N/mm^2$

Therefore, the panel will withstand the above condition including safety factor 1.26.

(2) How to calculate deflection

The deflection of ALPOLIC/fr panel can be calculated with the following equation:

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



Where,

Deflection: Maximum deflection of ALPOLIC panel
b: Panel width or height, whichever shorter side
A: Coefficient dependent on a/b ratio (length/width)
w: Wind pressure (kPa, kN/ m^2 or kg/m^2)
E_{AP}: Bending elastic modulus of ALPOLIC/fr (N/mm^2 or kg/mm^2)
t_{AP}: Thickness of ALPOLIC/fr (mm)

$E_{AP} \cdot t_{AP}^3$ is given in the following table:

ALPOLIC/fr	$E_{AP} \cdot t_{AP}^3$ (N·mm)	$E_{AP} \cdot t_{AP}^3$ (kg·mm)
3 mm	1323×10^3	135.0×10^3
4 mm	2546×10^3	259.8×10^3
6 mm	6287×10^3	641.5×10^3

(4) Calculation example of deflection

A. Premise

Wind load: 1.5 kPa (1.5 kN/m^2 = 153 kg/m^2)
ALPOLIC/fr thickness: 4 mm
Panel size: 1220×2440 mm
Supporting condition: 4-side fixed

B. Result

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

Where,

a/b=2.0, then A = 0.0277 (from Table 2 or White Binder P.12)

$Deflection = 0.0277 \times 1500 \times 10^{-6} \times 1220^4 / (2546 \times 10^3)$

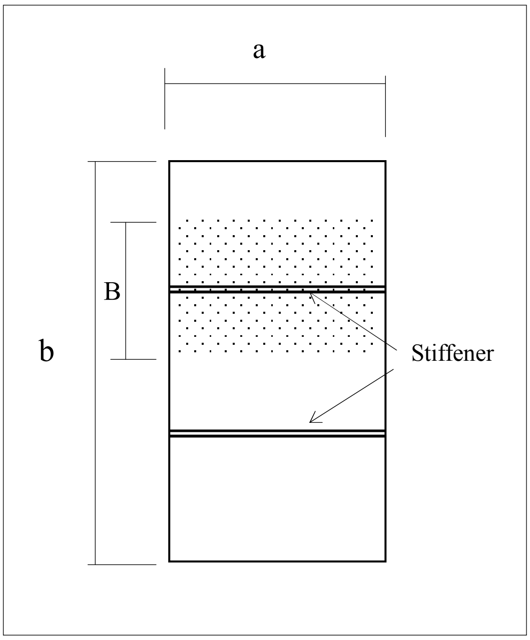
$= 36\ mm$

2. Strength design reinforced with stiffener

As a result of the above calculation, when the maximum stress exceeds the permissible stress of aluminium skin, or when the maximum deflection exceeds the project requirement, we will study to reinforce the panel with stiffener as one of the alternative solutions. In this study, we select a stiffener and evaluate whether the stiffener withstands the given condition or not. The rigidity of typical stiffeners are summarised in Table 3.

(1) How to calculate stress

The bending moment over the area B is given with the following equation:



$M = W \cdot a^2 / 8$ (N·mm)

Where,

W: Wind pressure loaded on the area B

$W = w \cdot B$

(w : uniform distributed load, N/mm^2)

This bending moment is shared by stiffener and ALPOLIC/fr panel respectively as follows:

Stiffener: $M_1 = M \cdot I_1 / (I_1 + I_2)$

ALPOLIC/fr: $M_2 = M \cdot I_2 / (I_1 + I_2)$

Where,

I_1: Moment of inertia of stiffener (refer to Table 3)

I_2 : Moment of inertia of ALPOLIC/fr, given with the following equation:

$I_2 = B \cdot (H^3 - h^3) / 12$ (mm^4)

B: Length of the area B (mm)

H: ALPOLIC/fr thickness (mm)

h: Thickness of core material, or internal span between aluminium skin sheets (mm)

Then, the bending stress is given with the following equation:

$Stress_1 = M_1 / Z_1$ (Stress in stiffener)

$Stress_2 = M_2 / Z_2$ (Stress in ALPOLIC/fr)

Where,

Z_1: Section modulus of stiffener (refer to Table 3)

Z_2: Section modulus of ALPOLIC/fr, given with the following equation:

$Z_2 = B \cdot (H^3 - h^3) / 6H$ (mm^3)

Permanent deformation will not occur within the following range:

$Stress_1 < Stress_{1Y}$ (for Stiffener)

$Stress_2 < Stress_{2Y}$ (for ALPOLIC/fr)

Where,

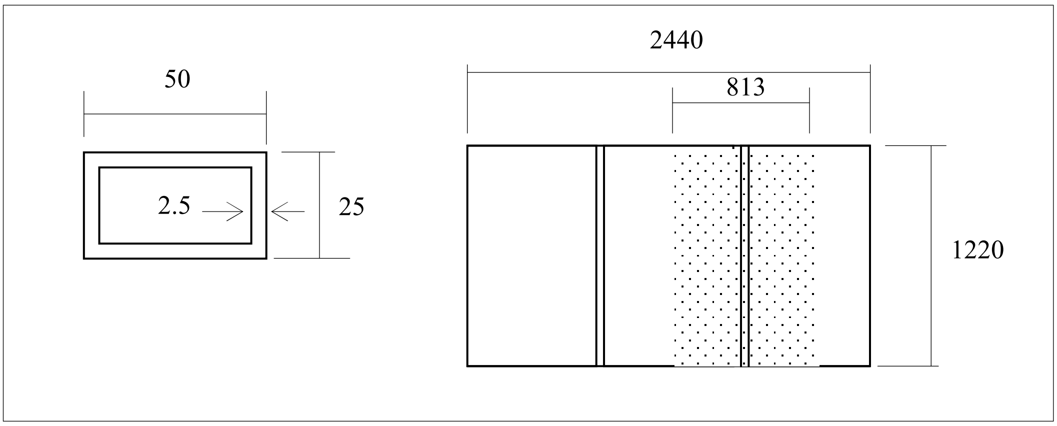
$Stress_{1Y}$: 0.2% proof stress (yield stress) of stiffener (refer to Table 3)

$Stress_{eY}$: 0.2% proof stress (yield stress) of aluminium skin of ALPOLIC/fr (152 N/mm^2)

(2) Calculation example of stress

A. Premise

Wind load: 2.5 kPa (=2.5 kN/m^2 = 255 kg/m^2)
ALPOLIC/fr thickness: 4 mm
Panel size: 1220×2440 mm
Supporting condition: 4-side fixed
Stiffener: 50×25×2.5mm t, aluminium extrusion (A6063, T5), 2 pieces per panel



B. Moment of inertia and section modulus

Stiffener: $I_1 = 3.51\times10^4$ mm^4
$Z_1 = 2.81\times10^3$ mm^3

ALPOLIC/fr: $I_2 = B\cdot(H^3 - h^3) / 12 = 813\times(4^3 - 3^3) / 12$
$= 0.25\times10^4$ mm^4
$Z_2 = B\cdot(H^3 - h^3) / 6H = 813\times(4^3 - 3^3) / 24$
$= 1.25\times10^3$ mm^3

Stiffener+ALPOLIC/fr: $\Sigma I = I_1 + I_2 = 3.76\times10^4$ mm^4

C. Calculation of stress

Bending moment: $M = W\cdot a^2 / 8$
$= 2500\times10^{-6}\times813\times1220^2 / 8 = 37.81\times10^4$ N·mm

Stiffener's share: $M_1 = M\cdot I_1 / (I_1 + I_2)$
$= 37.81\times10^4\times 3.51 / 3.76 = 35.30\times10^4$

ALPOLIC/fr's share: $M_2 = M\cdot I_2 / (I_1 + I_2)$
$= 37.81\times10^4\times 0.25 / 3.76 = 2.51\times10^4$

Bending stress: $Stress_1 = M_1 / Z_1$
$= 35.30\times10^4 / 2.81\times10^3 = 126 < 147$ N/mm^2 (OK)
$Stress_2 = M_2 / Z_2$
$= 2.51\times10^4 / 1.25\times10^3 = 20 < 152$ N/mm^2 (OK)

Therefore, the panel will withstand the above conditions including safety factor 1.17 for stiffener.

(3) How to calculate deflection

As for the deflection, respective deflection of stiffener and ALPOLIC is calculated first, and then the total deflection is given as a combined sum.

Deflection of stiffener:

$Deflection_1 = 5\,W\cdot a^4 / 384\,E_1\cdot I_1$ (mm)

Where,
E_1: Elastic modulus of stiffener (=70000 N/mm^2)

Deflection of ALPOLIC/fr:
$Deflection_2 = A \cdot w \cdot b^4 / (E_{AP} \cdot t_{AP}^3)$ (mm)

Combined deflection can be calculated with the following equation:
$Deflection = Deflection_1 \times Deflection_2 / (Deflection_1 + Deflection_2)$ (mm)

(4) Calculation example of deflection

A. Premise (the same conditions as above)

Wind load:	2.5 kPa (=2.5 kN/m^2 = 255 kg/m^2)
ALPOLIC/fr thickness:	4 mm
Panel size:	1220×2440 mm
Supporting condition:	4-side fixed
Stiffener:	50×25×2.5mm t, aluminium extrusion (A6063, T5), 2 pieces per panel

B. Deflection

Deflection of stiffener:

$Deflection_1 = 5 W \cdot a^4 / 384 E_1 \cdot I_1$
$= 5 \times 3000 \times 10^{-6} \times 813 \times 1220^4 / (384 \times 70000 \times 3.51 \times 10^4)$
$= 28.6$ mm

Deflection of ALPOLIC:

$Deflection_2 = A \cdot w \cdot b^4 / (E_{AP} \cdot t_{AP}^3)$

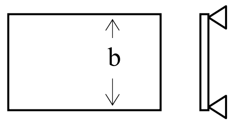
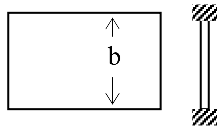
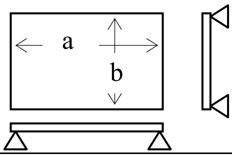
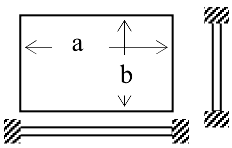
Where,
a/b=1220/813=1.50, then A=0.0838 (from Table 2 or White Binder P.12)

$Deflection_2 = 0.0838 \times 3000 \times 10^{-6} \times 813^4 / (2546 \times 10^3)$
$= 43.1$ mm

Combined deflection:

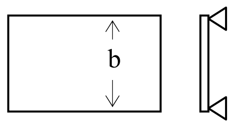
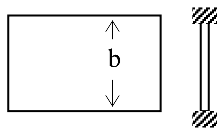
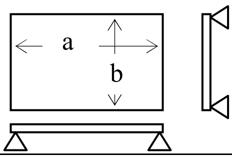
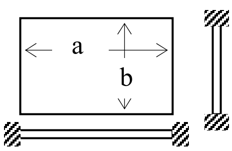
$Deflection = Deflection_1 \times Deflection_2 / (Deflection_1 + Deflection_2)$
$= 28.6 \times 43.1 / (28.6 + 43.1)$
$= 17.2$ mm

Table 1 Coefficient B for calculation of stress

<table>
<tr><th>Support condition</th><th></th><th colspan="8">Equation and B value</th></tr>
<tr><td>2-side simply supported and 2-side free</td><td></td><td colspan="8">$\text{Stress}_M = 0.75\cdot w\cdot b^2 / t^2$</td></tr>
<tr><td>2-side fixed and 2-side free</td><td></td><td colspan="8">$\text{Stress}_M = 0.5\cdot w\cdot b^2 / t^2$</td></tr>
<tr><td rowspan="3">4-side simply supported</td><td rowspan="3"></td><td colspan="8">$\text{Stress}_M = B\cdot w\cdot b^2 / t^2$</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></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></tr>
<tr><td rowspan="3">4-side fixed</td><td rowspan="3"></td><td colspan="8">$\text{Stress}_M = B\cdot w\cdot b^2 / t^2$</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></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></tr>
</table>

Note: The above is an excerpt from White Binder P.10. Refer to White Binder for other cases.

Table 2 Coefficient A for calculation of deflection

<table>
<tr><th>Support condition</th><th></th><th colspan="9">Equation and A value</th></tr>
<tr><td>2-side simply supported and 2-side free</td><td></td><td colspan="9">$\text{Deflection} = 0.156\cdot w\cdot b^4 / (E_{AP}\cdot t_{AP}^3)$</td></tr>
<tr><td>2-side fixed and 2-side free</td><td></td><td colspan="9">$\text{Deflection} = 0.0313\cdot w\cdot b^4 / (E_{AP}\cdot t_{AP}^3)$</td></tr>
<tr><td rowspan="3">4-side simply supported</td><td rowspan="3"></td><td colspan="9">$\text{Deflection} = A\cdot w\cdot b^4 / (E_{AP}\cdot t_{AP}^3)$</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">$\text{Deflection} = A\cdot w\cdot b^4 / (E_{AP}\cdot t_{AP}^3)$</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>
</table>

Note: The above is an excerpt from White Binder P.12. Refer to White Binder for other cases.

Table 3. Rigidity of Various Stiffeners

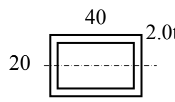
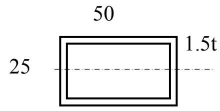
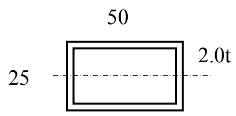
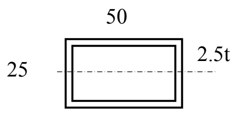
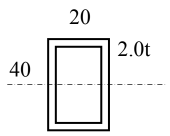
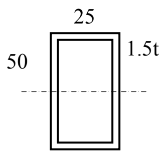
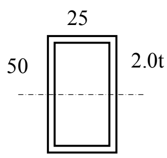
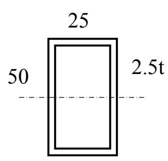
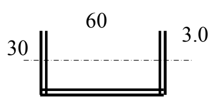
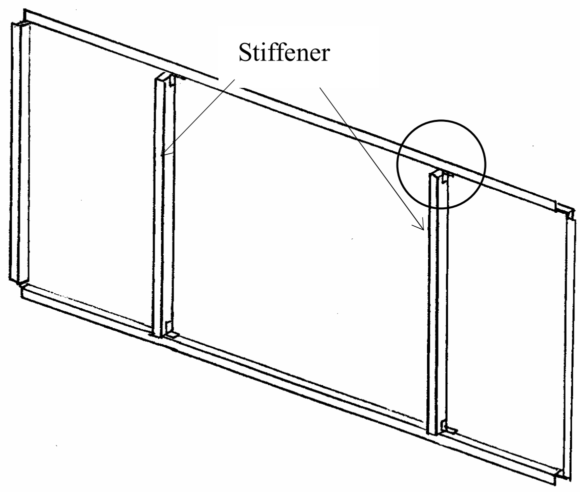
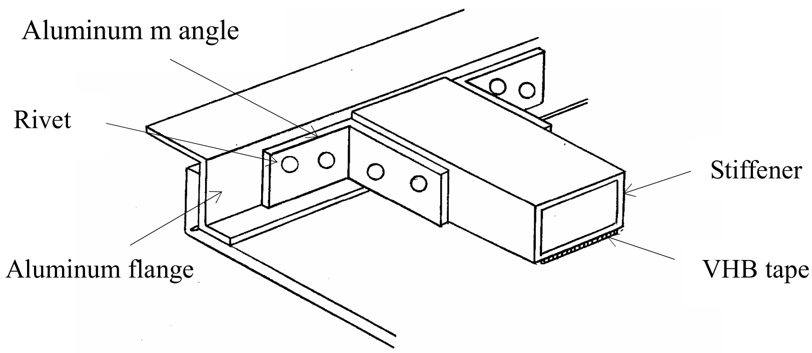
Stiffener / Material (Unit weight)		Moment of inertia (I_X, mm^4)	Section modulus (Z_X, mm^3)	0.2% proof stress (N/mm^2)
Aluminium extrusion 40×20×2.0mmt 6063S-T5 (640g/m)		$I_X = 1.44\times10^4$	$Z_X = 1.44\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×1.5mmt 6063S-T5 (600g/m)		$I_X = 2.34\times10^4$	$Z_X = 1.87\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×2.0mmt 6063S-T5 (800g/m)		$I_X = 2.96\times10^4$	$Z_X = 2.36\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×2.5mmt 6063S-T5 (1000g/m)		$I_X = 3.51\times10^4$	$Z_X = 2.81\times10^3$	147 N/mm^2
Aluminium extrusion 40×20×2.0t 6063S-T5 (640g/m)		$I_X = 4.45\times10^4$	$Z_X = 2.22\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×1.5t 6063S-T5 (600g/m)		$I_X = 7.01\times10^4$	$Z_X = 2.80\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×2.0t 6063S-T5 (800g/m)		$I_X = 9.01\times10^4$	$Z_X = 3.60\times10^3$	147 N/mm^2
Aluminium extrusion 50×25×2.5t 6063S-T5 (1000g/m)		$I_X = 10.85\times10^4$	$Z_X = 4.34\times10^3$	147 N/mm^2
Aluminum sheet 60×30×3.0t 1100-H24 (970g/m)		$I_X = 2.80\times10^4$	$Z_X = 1.35\times10^3$	118 N/mm^2

Fig. 1 Fixation method of stiffener

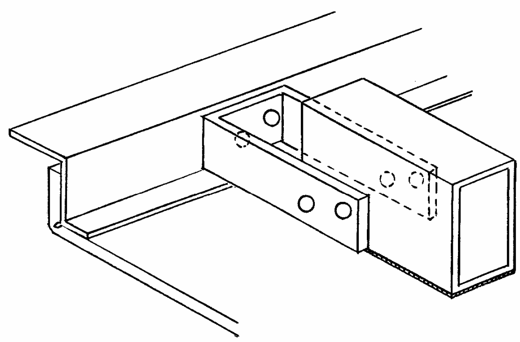
ALPOLIC/fr panel reinforced with stiffener - from reverse side



Example A



Example B



Deforming test due to shearing force parallel to panel surface

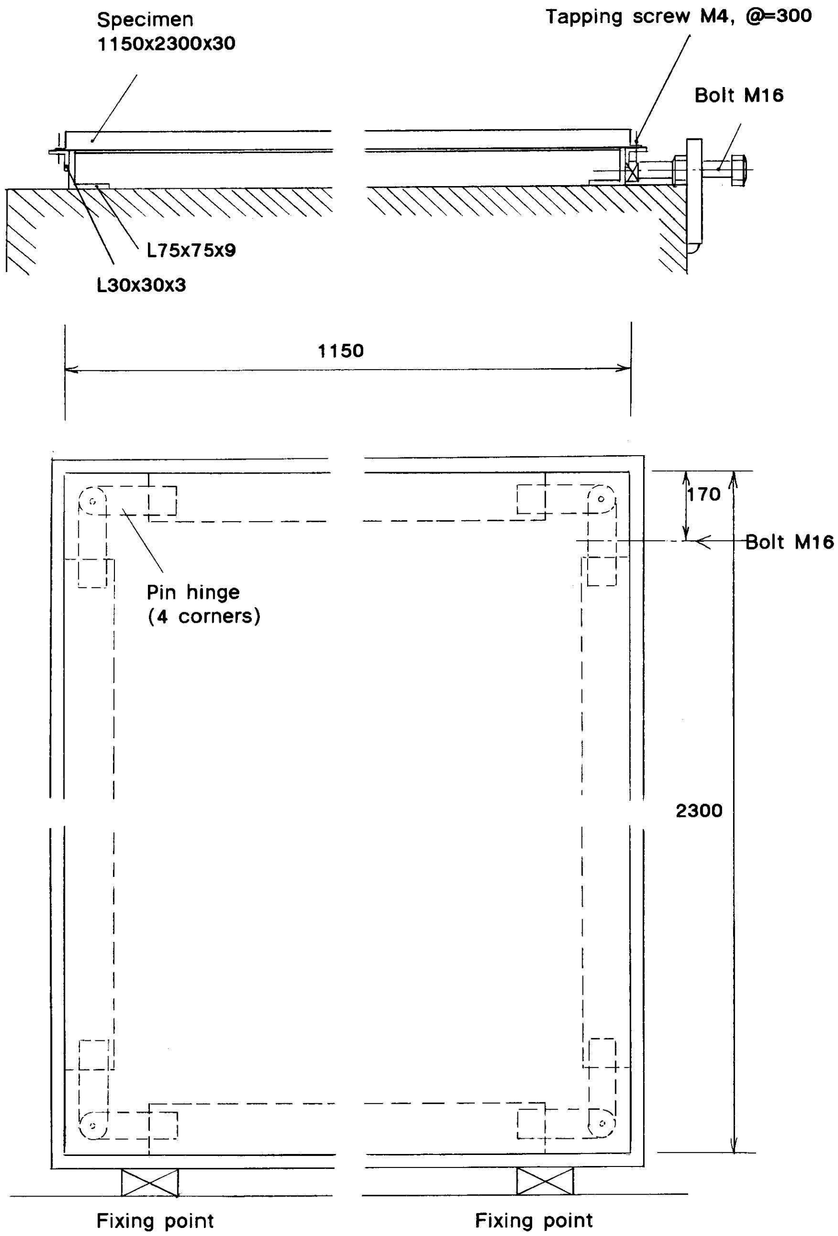
1. Test method
   The test was held in accordance with JIS A1414 "Deforming test of non-bearing wall panel due to shearing force parallel to panel surface."

(1) Specimen
1150×2300 Tray type panel
(Panel depth: 30mm)
Material: ALPOLIC 4mm

(2) Test apparatus
The test apparatus is shown in Fig. 1. The specimen is fixed onto L30×30×3mm angle of the holder with tapping screw. Bolt M16 is equipped at one corner to apply a shearing force parallel to the panel surface.

(3) Test method
Tighten the bolt M16 until the measurement point D1 reaches P_1=1/400, P_2=1/300, P_3=1/200, P_4=1/150, P_5=1/100, P_6=1/75 and P_7=1/50. P shows a ratio of horizontal displacement to panel height. Observe the following items:
A: Deformation and remaining deflection of the specimen and fixing points.
B: Noise of breakage
C: Peel-off or de-lamination of finishing material.
D: Crack or gap penetrating the panel and fixation points.

Fig. 1 Test apparatus



2. Test result

(1) Displacement and panel deflection

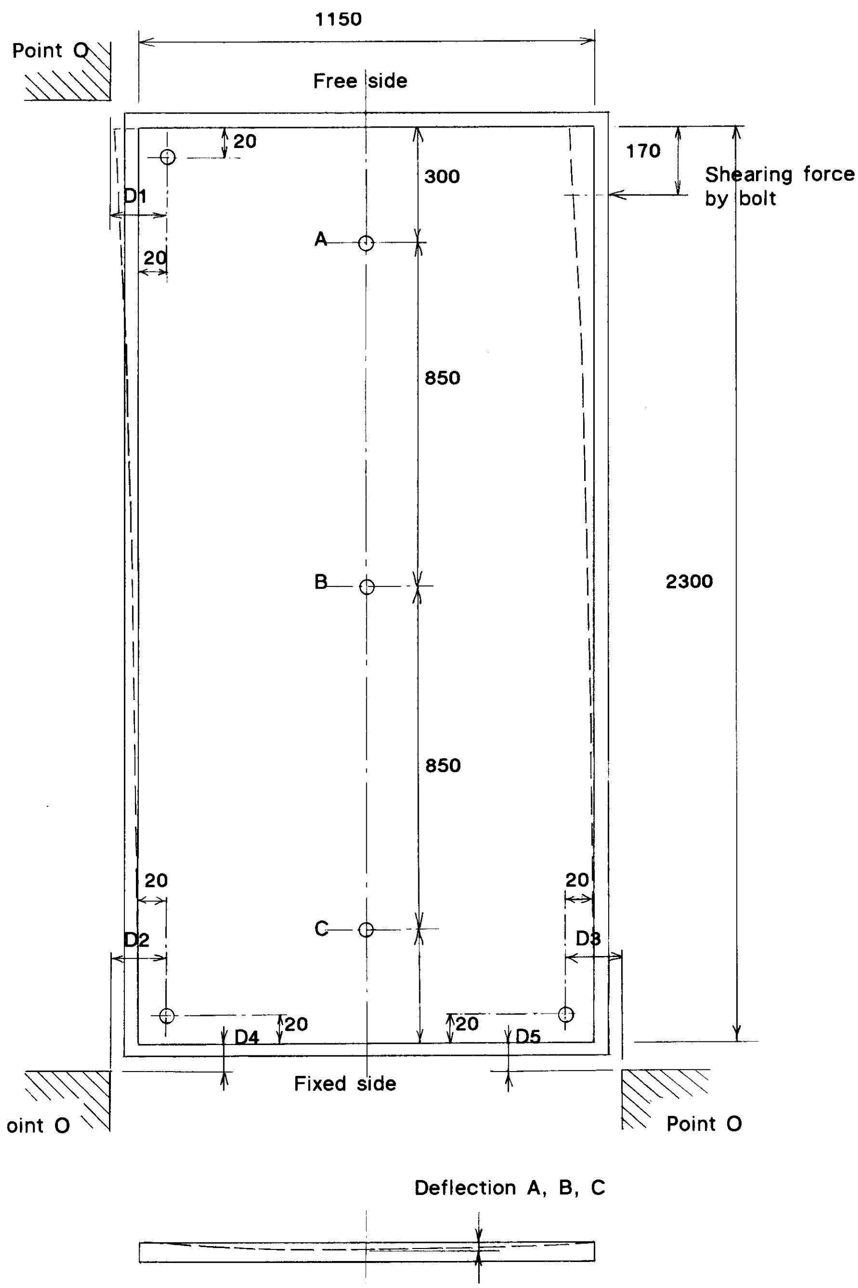
Displacement ratio (P)	Initial	1/400	1/300	1/200	1/150	1/100	1/75	1/50
Displacement (mm)								
D1	0	6	8	11	16	23	31	46
D2	-	0	0	0	0	0	0	0
D3	-	-1	-2	-1	-1	-1	-2	-1
D4	-	-3	-4	-5	-6	-9	-11	-16
D5	-	0	0	1	1	3	4	6
Deflection (mm)								
A	-	0	0	0	0	0	0.8	1.0
B	-	0	0	0	0	0	0.5	0.5
C	-	0	0	0	0.5	0.5	2.0	3.0

Note: The positions of measurement points are shown in Fig. 2.

(2) Observation during and after the test

The panel, flange and fixation point with tapping screw was normal during and after the test. The displacement was absorbed in the panel deflection, which was completely restored to the original position when the displacement was eliminated after the test. Any problem was not observed in other assemblies of the tray type panel.

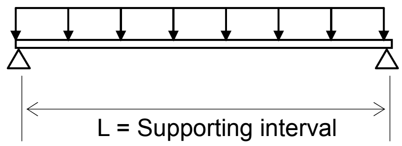
Fig. 2, Measurement points



Strength of sub-structure

1. Calculation method

For structural calculation, sub-structure can be handled as a beam, on which wind load is uniformly distributed. Normally, sub-structure is deemed as a part of structure, and so L/200 rule (L: supporting interval of sub-structure) is applied on the deflection of sub-structure. Therefore, sub-structure must meet two conditions:

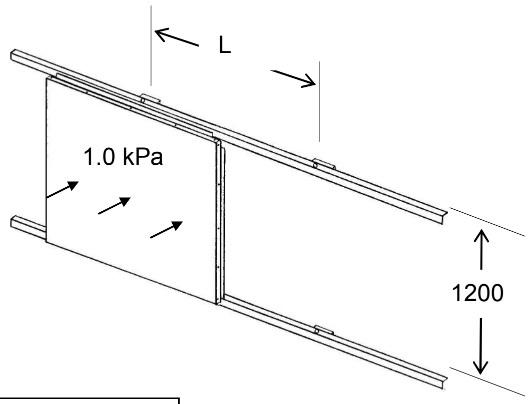


(1) Maximum stress not to exceed the permissible stress
(2) Maximum deflection not to exceed L/200.

The above conditions are expressed with equations in the following manner:

(1) Stress
$Z > W \bullet L^2 / (8 \bullet Stress_{0.2})$
where, Z: Section modulus of sub-structure (mm^3)
W: Wind load on sub-structure (N/mm)
L: Supporting interval of sub-structure (mm)
$Stress_{0.2}$: 0.2% proof stress of sub-structure (N/mm^2)

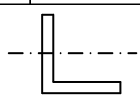
(2) Deflection
$5 \bullet W \bullet L^4 / 384 \bullet E \bullet I < (L/200)$
where, E: Modulus of elasticity of sub-structure (N/mm^2)
I: Moment of inertia of sub-structure (mm^4)



2. Calculation example

2-1. Premise

(1) Wind load: 1.0kPa ($1.0kN/m^2 = 98kg/m^2$)
(2) Panel width: 1200mm
(3) Supporting interval: L (mm, to be determined)
(4) Sub-structure: L40×40×3.0mm made of steel or aluminum, as shown below:

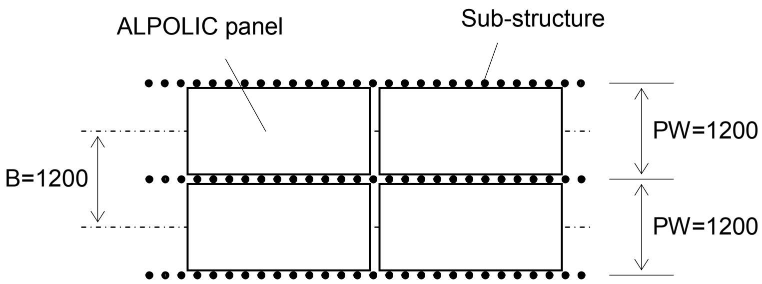
	Sub-structure material	
	Steel	Aluminum
Section Moment of inertia Section modulus	L40×40×3.0mm $I = 3.53 \times 10^4$ mm^4 $Z = 0.121 \times 10^4$ mm^3	
0.2% proof stress Modulus of elasticity	$Stress_{0.2} = 235N/mm^2$ $E = 210kN/mm^2$	$Stress_{0.2} = 117N/mm^2$ $E = 70kN/mm^2$

2-2. Wind load on sub-structure

$W = w \bullet B$
$= 1000N/m^2 \times 10^{-6} mm^2/m^2 \times 1200mm$
$= 1.20N/mm$

B: Loading width as shown in the diagram below

2-3. In case of steel sub-structure



[Stress]

$Z > W \cdot L^2 / (8 \cdot Stress_{0.2})$

$0.121\times10^4 > 1.20\times L^2/(8\times235)$

L < 1377 mm

[Deflection]

$5 \cdot W \cdot L^4 / 384 \cdot E \cdot I < (L/200)$

$5\times1.20\times L^4 / 384\times210000\times3.53\times10^4 < (L/200)$

L < 1333 mm

To meet both stress and deflection conditions, L < 1333 mm. Namely, the supporting interval must be smaller than 1333 mm.

2-4. In case of aluminum sub-structure

[Stress] $Z > W \cdot L^2 / (8 \cdot Stress_{0.2})$

$0.121\times10^4 > 1.20\times L^2/(8\times117)$

L < 971 mm

[Deflection] $5 \cdot W \cdot L^4 / 384 \cdot E \cdot I < (L/200)$

$5\times1.20\times L^4 / 384\times70000\times3.53\times10^4 < (L/200)$

L < 925 mm

To meet both stress and deflection conditions, L < 925 mm. Namely, the supporting interval must be smaller than 925 mm.

2-5. Conclusion

The calculated results are summarised as follows:

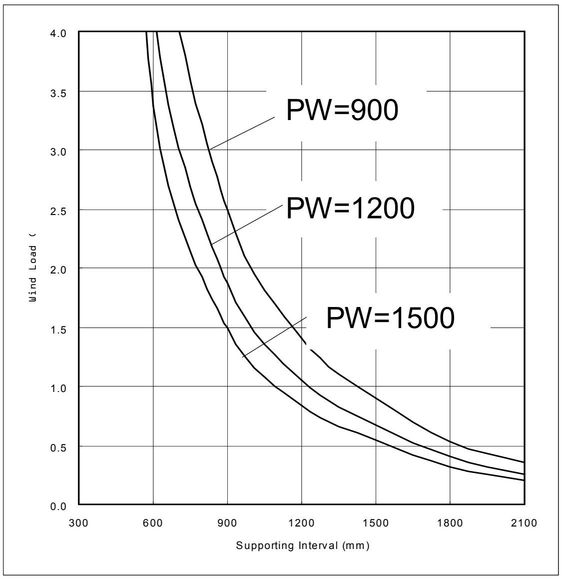
Sub-structure material	Supporting interval
Steel	< 1333 mm
Aluminum	< 925 mm

3. Support intervals of sub-structure for general purpose

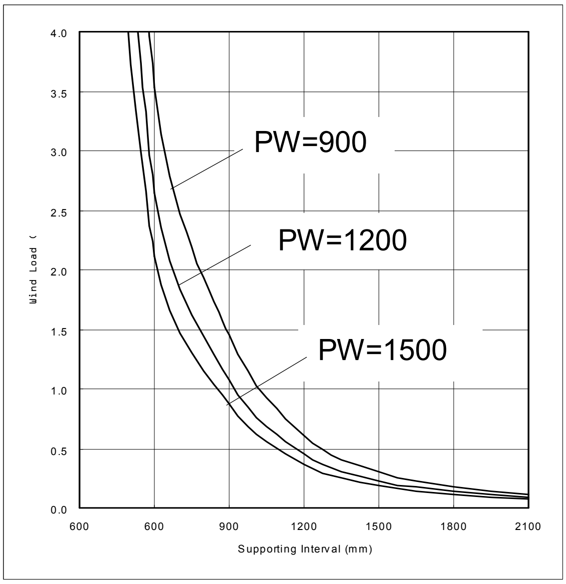
The following charts are calculation results for suitable intervals of L-40×40×3mm made of steel or aluminum. This calculation is based on the following premise:

Sub-structure material	Steel L-40×40×3mm Galvanised or coated with rust-preventive paint	AluminumL-40×40×3mm Alloy: 6063 T5
Moment of inertia	$I = 3.53\times10^4$ mm^4	$I = 3.53\times10^4$ mm^4
Section modulus	$Z = 0.121\times10^4$ mm^3	$Z = 0.121\times10^4$ mm^3
Permissible stress (including safety factor=1.25)	$Stress_P = 210$N/mm^2	$Stress_P = 118$N/mm^2
Modulus of elasticity	E = 210kN/mm^2	E = 70kN/mm^2

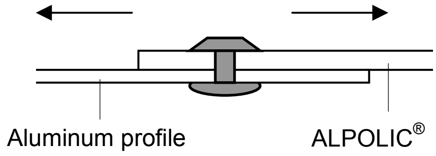
Steel L-40×40×3mm



Aluminum L-40×40×3mm

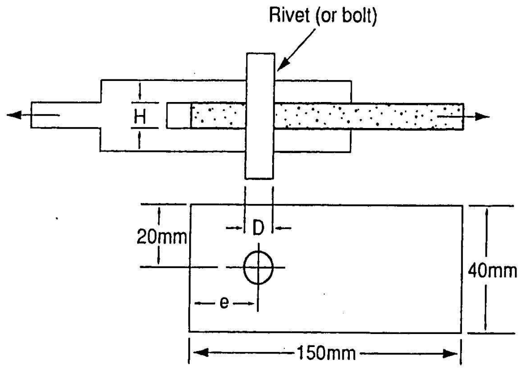


Strength of junction hole



Test method for junction hole

Rivet, bolt/nut and tapping screw are quite often used for junction between ALPOLIC® panels and aluminum profiles. When tensile force loads on the junction point, stress will arise in the junction hole of ALPOLIC® panel. In order to evaluate the maximum elastic limit of junction hole, test was performed. The results are shown in the table below:



To utilize this table, we convert the stress to tensile force with the following equation:

F = Stress × t × D
Where, Stress: Maximum elastic stress (N/mm^2)
F: Maximum tensile force (N)
t: Thickness of ALPOLIC®
D: Hole diameter

Calculation example:
Premise: ALPOLIC® 305, D = 4 mm, e = 8 mm,
Result: F = Stress × t × D = 48×3×4 = 576 N per junction point

Hole diameter D (mm)	Hole center to panel edge e (mm)	Max. elastic stress (N/mm^2)			Max. tensile force, F (N)		
		3mm	**4mm**	**6mm**	**3mm**	**4mm**	**6mm**
5	5	21	23	18	320	430	530
	10	48	44	38	720	880	1150
	15	55	46	40	820	920	1210
10	9	20	21	17	590	820	1000
	19	38	33	25	1150	1330	1530
	30	39	38	25	1170	1530	1470

It is understood from the above table that, if the hole position is in the proximity of edge, the hole strength lessens to one half of its original strength. In order to ensure a reasonable strength of junction hole, the distance from the center of hole to the edge (e) should be larger than double of hole-diameter (D): namely, e > 2×D.

Heat Transmission of External Cladding

1. Mechanism of heat transmission

The heat transmits by three mechanisms of radiation, convection and conduction:

Radiation: The heat transmission by a thermal energy, evolved from an object, reaching another object, to increase the latter temperature.

Convection: The heat transmission by movement of fluid, like air or water. When a part of fluid is warmed, and then, the part of fluid moves upward due to the lightened density.

Conduction: The internal heat transmission in solid material.

2. Heat conduction

Among these mechanisms, the heat transmission dealt with external claddings is primarily dependent on the heat conduction of the wall materials.

When a temperature difference exists between both sides of wall, heat flows from the higher temperature end to the lower temperature end by heat conduction, and the speed of heat flow is defined as the heat conductivity, which is expressed by the following equation:

$Q = (L/ d) \cdot (t_1 - t_2)$

where

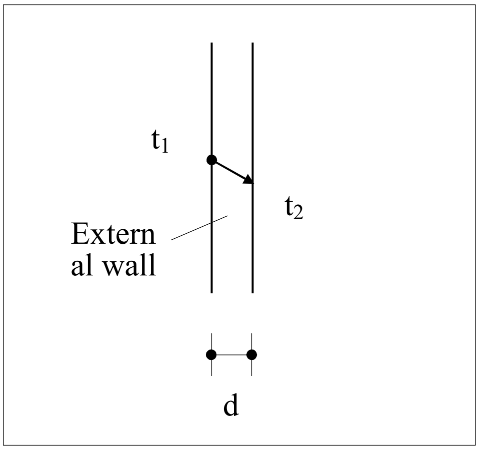
Q: Total heat flow by heat transmission (kcal/m^2h)

L: Heat conductivity (kcal/mh°C)

$t_{1,2}$: Surface temperature of wall (°C)

d: Wall thickness (m)

Fig. 1, Heat Conduction



The heat conductivity of ALPOLIC/fr is given as a combined conductivity of aluminum and core material, and it is a relatively small value, compared with aluminum and steel. The heat conductivity of various wall materials is summarized in Table 1.

Table 1, Heat Conductivity of Various Wall Materials

Materials	Heat Conductivity kcal/mh°C	Materials	Heat Conductivity kcal/mh°C	Materials	Heat Conductivity kcal/mh°C
ALPOLIC/fr 3mm	0.43	Float Glass	0.86	Gypsum Board	0.11
ALPOLIC/fr 4mm	0.39	Granite	2.50	Rock Wool	0.035
ALPOLIC/fr 6mm	0.35	Concrete	1.40	Glass Wool	0.035
Aluminum Sheet	180.0	Mortar	1.30	Polyurethane Foam	0.035
Steel Sheet	39.0	Brick	0.24	Styrofoam	0.030

3. Heat transmission

Apart from the heat conduction through wall materials, there is another heat flow in the interface between the wall and the adjacent air. This heat flow of interface, caused by a concurrent occurrence of heat radiation, convection and conduction, is called the heat transfer.

When there is a temperature difference in atmosphere between both sides of wall, the heat flows from the higher temperature to the lower temperature, through the heat transfer (air to wall), heat conduction inside the wall and heat transfer (wall to air). The overall heat flow process is called the heat transmission.
This process can be expressed by the following equation:

$Q = K \cdot (t_1 - t_2)$
$K = 1 / (1/A_o + d/L + 1/A_i)$
Where
Q: Total heat flow by heat transmission (kcal/m^2h)
K: Heat transmission coefficient (U Value, kcal/m^2h°C)
$t_{1,2}$: Atmospheric temperature around wall (°C)
$A_{o,i}$: Heat transfer coefficients (kcal/m^2h°C)
L: Heat conductivity (kcal/mh°C)
d: Wall thickness (m)

The above K-value, called the heat transmission coefficient, indicates the easiness of heat flow through the wall. The lower the K-value is, the thermal insulation of the wall system becomes better.
This value is also called U-value and expressed in W/($m^2 \cdot$ K) in the SI unit in accordance with ISO. The values can be converted each other by the following equation:

W/($m^2 \cdot$ K)×0.86 = kcal/m^2h°C

4. Heat transmission of actual wall
The heat transmission coefficient of actual wall system, as shown in Fig. 3, can be calculated by summing up each component of heat flow, from the outer surface of ALPOLIC/fr panel to the inner surface of interior material. Refer to Table 2.

Fig. 2, Heat Transmission

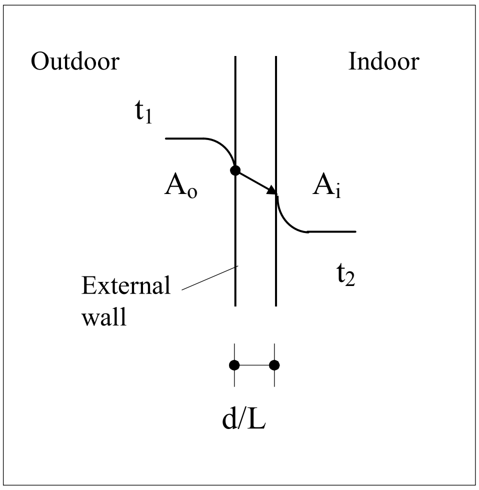


Fig. 3, Heat Transmission of Actual Wall

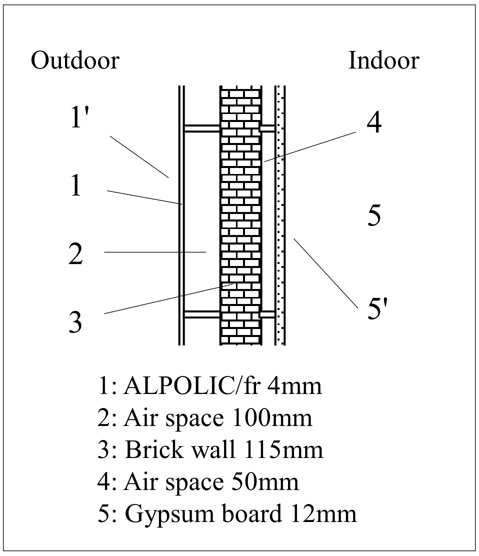


Table 2, Example of Calculation of Heat Transmission Coefficient

No.	Component of heat flow	Equation	Value, kcal/m^2h°C
1'	Heat transfer from outer air to ALPOLIC/fr	$1/A_o$	0.05
1	Internal heat conduction in ALPOLIC/fr	d_1/L_1	0.004/0.39=0.01
2	Internal heat transfer in air space	d_2/L_2	0.10
3	Internal heat conduction in brick wall	d_3/L_3	0.115/0.24=0.48
4	Internal heat transfer in air space	d_4/L_4	0.10
5	Internal heat conduction in gypsum board	d_5/L_5	0.012/0.11=0.11
5'	Heat transfer from gypsum board to inner air	$1/A_I$	0.13
	Total	$1/K=1/A_o+\Sigma d_i/L_i+1/A_i$	1/K=0.98 K=1.02 kcal/m^2h°C

Generally, the heat transmission coefficient of actual wall system can be expressed with the following equation:

$1/K = 1/A_o + \Sigma d_i/L_i + 1/A_I$

Where, d_i/L_i : Heat conduction of each wall materials or heat transfer of air space

3. Heat transmission coefficient of various wall system

By means of the above equation, the heat transmission coefficient can be calculated for various types of wall systems. In order to clarify the insulation effect of ALPOLIC/fr, the heat transmission coefficient, K-value or U- value, was calculated for some typical wall systems, in which the components constituting the wall system were selected among the following alternatives:

	Wall component
1. External cladding	(1) ALPOLIC/fr (2) Solid aluminum panel (3) Float glass
2. Thermal insulation	(1) None (2) Glass wool 25mm (3) Glass wool 50mm
3. Structural wall or fireproof material	(1) RC wall (2) Brick wall (3) Gypsum board 16+16mm
4. Interior material	(1) None (2) Gypsum board 12mm

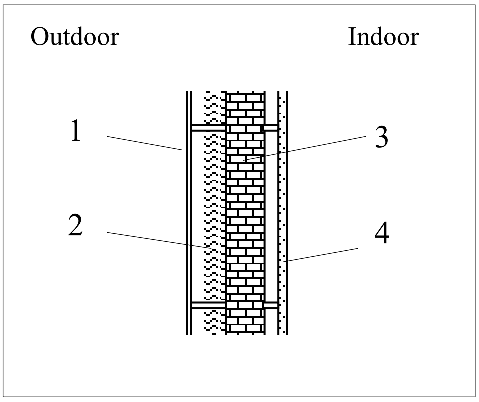


Table 3, Heat transmission coefficient of external wall (1)

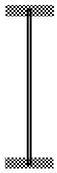
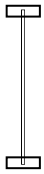
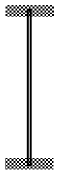
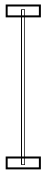
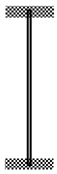
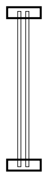
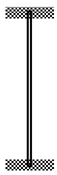
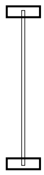
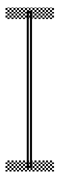
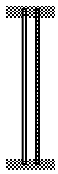
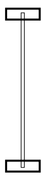
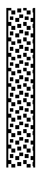
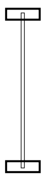
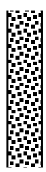
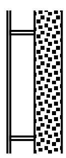
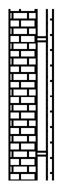
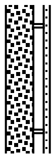
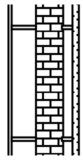
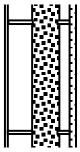
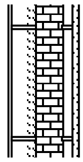
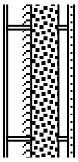
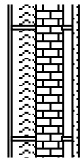
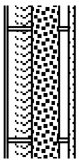
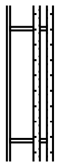
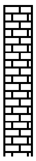
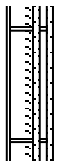
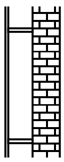
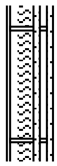
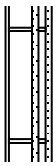
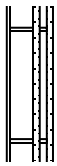
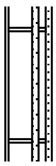
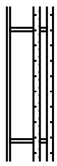
Wall System (Thickness, mm)		Heat Transmission Coefficient (U Value)		Wall System (Thickness, mm)		Heat Transmission Coefficient (U Value)	
		kcal/m^{2}h°C	(W/m^2•K)			kcal/m^{2}h°C	(W/m^2•K)
ALPOLIC/fr 3mm only		5.4	(6.2)	Heat Absorbing Float Glass Bronze 6mm		5.0	(5.8)
ALPOLIC/fr 4mm only		5.3	(6.1)	High Performance Reflective Glass 6mm		3.9-4.6	(4.6-5.4)
ALPOLIC/fr 6mm only		5.1	(5.9)	Double Glazing Glass, Reflective Glass 6mm + Airspace 12mm +FL6		1.5-2.3	(1.9-2.6)
Aluminum Sheet 3mm		5.6	(6.5)	Polycarbonate Sheet, Clear 3mm		5.2	(6.0)
Aluminum Sheet 4mm		5.6	(6.5)	ALPOLIC/fr 4 Air Space 50 Gypsum Board 12		2.5	(2.9)
Float Glass Clear 3mm		5.1	(6.0)	Reinforced Concrete 100mm		4.0	(4.6)
Float Glass Clear 6mm		5.0	(5.8)	Reinforced Concrete 150mm		3.5	(4.1)
ALPOLIC/fr 4 Air Space 100 RC Wall 100		2.8	(3.2)	Brick Wall 115 Air Space 50 Gypsum Board 12		1.2	(1.3)

Table 3, Heat transmission coefficient of external wall (1)

Wall System (Thickness, mm)		Heat Transmission Coefficient (U Value)		Wall System (Thickness, mm)		Heat Transmission Coefficient (U Value)	
		kcal/m²h°C	(W/m²•K)			kcal/m²h°C	(W/m²•K)
RC Wall 100 Air Space 50 Gypsum Board 12		2.2	(2.5)	ALPOLIC/fr 4 Air Space 100 Brick Wall 115 Air space 50 Gypsum Board 12		1.0	(1.2)
ALPOLIC/fr 4 Air Space 100 RC Wall 100 Air Space 50 Gypsum Board 12		1.8	(2.1)	ALPOLIC/fr 4 Air Space 75 Glass Wool 25 Brick Wall 115 Air space 50 G. Board 12		0.59	(0.69)
ALPOLIC/fr 4 Air Space 75 Glass Wool 25 RC Wall 100 Gypsum Board 12		0.79	(0.92)	ALPOLIC/fr 4 Air Space 50 Glass Wool 50 Brick Wall 115 Air space 50 G. Board 12		0.42	(0.48)
ALPOLIC/fr 4 Air Space 50 Glass Wool 50 RC Wall 100 Air Space 50 G. Board 12		0.50	(0.58)	ALPOLIC/fr 4 Air Space 100 Gypsum Board 16, Air Space 50, Gypsum Board 16		1.5	(1.7)
Brick Wall 115mm		1.5	(1.8)	ALPOLIC/fr 4 Air Space 75 Glass Wool 25, G. Board 16, Air Space 50, G. Board 16		0.72	(0.83)
ALPOLIC/fr 4 Air Space 100 Brick Wall 115		1.3	(1.5)	ALPOLIC/fr 4 Air Space 50 Glass Wool 50, G. Board 16, Air Space 50, G. Board 16		0.47	(0.55)
ALPOLIC/fr 3mm Air Space 100 G. Board 16, Air Space 50, G. Board 16		1.48	(1.72)	Aluminum Panel 3mm Air Space 100 G. Board 16, Air Space 50, G. Board 16		1.49	(1.74)
ALPOLIC/fr 6mm Air Space 100 G. Board 16, Air Space 50, G. Board 16		1.46	(1.69)	Aluminum Panel 4mm Air Space 100 G. Board 16, Air Space 50, G. Board 16		1.49	(1.74)

General performance of sealant

Silicone sealant is widely known for its excellent long-term performance such as durability, thermal resistance and adhesion reliability. The following table shows general comparison among sealing materials for exterior.

General performance		Sealing Materials			
		Silicone	Modified silicone	Polysulfide	Polyurethane
Restoring ability		A	A-B	B	B
Degradation	Due to aging	VS	S-M	M	M
	Due to temperature	VS	S-M	M-L	M
Shrinkage after filling		S	S	S	S
Serviceable temperature (long-term)		-40/120°C	-30/90°C	-20/80°C	-20/70°C
Weatherability		A	A-B	A-B	B
Fatigue resistance		A	A-B	B	A-B

Note 1: A: Excellent B: Good C: Normal
VS: Very small S: Small M: Medium L: Large

Note 2: The above is excerpt from Sealing Material Handbook, Japan Sealant Manufacturers' Association.

But silicone sealant is also known for its staining problem. Especially, if silicone sealant is applied for natural stone wall, in which many small cavities exist on the surface, the staining problem becomes serious.

The following table is excerpt from "Architectural Technology No.4, P.90-93, 1993", architectural magazine published in Japan, focusing on the staining tendency of each sealing material. Recently, silicone sealant manufacturers have developed the less staining silicone sealant. The following table was prepared before this new type silicone emerged.

Stain		Sealing Materials			
		Silicone	Modified silicone	Polysulfide	Polyurethane
Surrounding area	Due to dispersed component	C	A	A	A
Sealing joint surface	Due to dust adhesion	C	B	A	C
	Due to mold grow	B	B	B	B
Color fading	Due to UV & sulfur	A	A	B	C

(Note) A: No affect, B: Small affect, C: Affect

Protection of ALPOLIC/fr Panels against Lightning

1. General understanding

In the event that lightning should strike the ALPOLIC/fr panel of external cladding, what will happen on the panel and the building? Generally speaking, external cladding panels constitute an electric circuit together with the sub-structure, which is finally connected to the ground earth. Therefore, it is a general understanding that the lightning electricity will flow toward the ground through the electric circuit, and nothing will happen on the panel and the building.

But, to be safe, we are going to verify the electric behavior of ALPOLIC/fr panel of external cladding more in detail, particularly when lightning strikes ALPOLIC/fr panel.

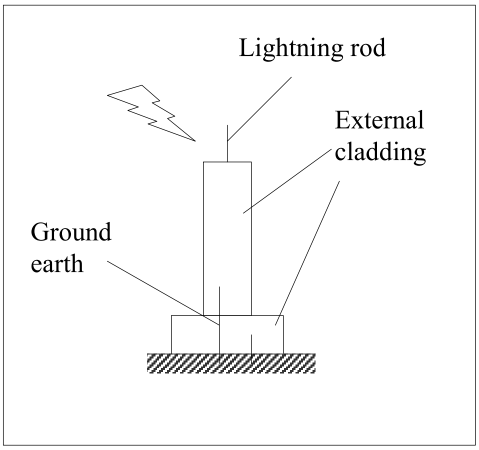


Fig. 1, Lightning on ALPOLIC/fr panel

2. Requirements for electric-conducting wire to release lightning electricity

When lightning strikes ALPOLIC panel of external cladding and the electricity flows through the electric circuit consisting of ALPOLIC panels and their sub-structure, if the electric resistance of the circuit is low enough, the electricity will pass through the circuit, like a electric-conducting wire, toward the ground. Thus, in order to act as a suitable electric-conducting wire to release the lightning electricity, the electric resistance of external cladding and sub-structure must be low enough. In accordance with JIS A 4201 "The protection of structures against lightning," the requirements for electric-conducting wire of lightning rod is standardized as follows:

(1) To provide every wire within 50m interval of perimeter of the building.
(2) The electric resistance of each wire shall be lower than 50 ohm and the overall resistance shall be lower than 10 ohm.

3. Electric resistance of ALPOLIC panels and sub-structure

According to the above standard, we would like to evaluate whether the electric resistance is low enough in ALPOLIC panels and sub-structure system. In order to evaluate the electric resistance, one model of external cladding was used: a rectangular solid building of 25m by 25m by 100m high, as shown in Fig.2.

ALPOLIC cladding and sub-structure are assumed to be surrounding the whole building. The installation method is assumed as Fig. 3. Sub-structure, coated steel, is fixed to the concrete slab with bracket and anchor. ALPOLIC panels are fixed onto the sub-structure with screw of stainless steel.

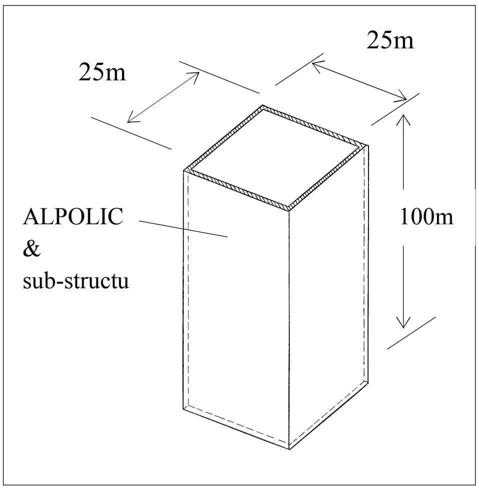


Fig. 2, Model for calculation

As the surfaces of ALPOLIC and sub-structure are coated with paint, both surfaces are electrically insulated.

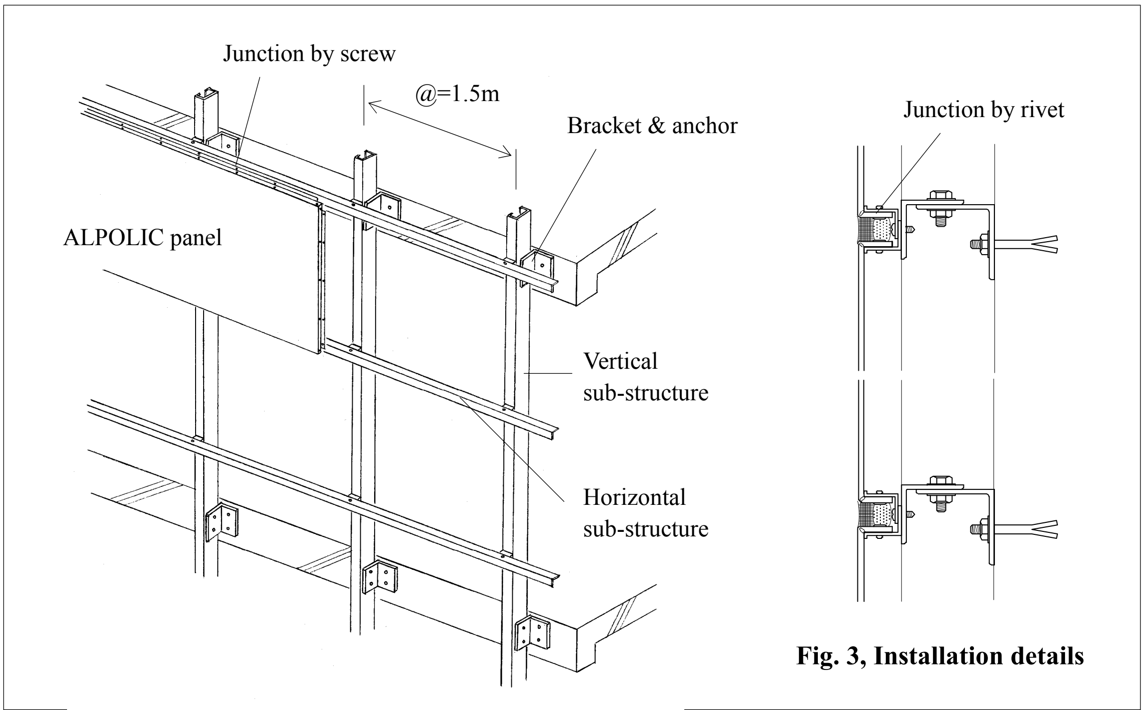


Fig. 3, Installation details

Therefore, the electrical connection between ALPOLIC panel and sub-structure will be ensured by means of junction points by rivets (aluminum) and screws (stainless steel) in this model. Based on the above assumption, when the contact resistance of these junction points is disregarded, the electric resistance of ALPOLIC panel and sub-structure from the building top and to the ground can be calculated as follows:

Table 1. Calculated electric resistance of external cladding

	ALPOLIC (aluminum skin of surface side, 0.5mmt)	Sub-structure (steel, 100×50×2mmt)	Combined resistance of aluminum and steel
Specific resistance of aluminum and steel	4×10^{-8}ohm·m	10×10^{-8} ohm·m	-
Sectional area of metals in the model	$0.05m^2$ ($0.5\times10^{-3}\times25m\times4$)	$0.027m^2$ ($0.2\times2\times10^{-3}\times66$pcs.)	-
Electric resistance from top to bottom	0.8×10^{-4} ohm	3.7×10^{-4} ohm	0.66×10^{-4} ohm

As shown in the above table, it is confirmed that the calculated resistance of external cladding is very low, compared with the standard value of 10ohm.

4. Survey at ALPOLIC project

To confirm the above calculation, we held a survey at actual ALPOLIC project (total ALPOLIC area is $300m^2$, as shown in Fig.4), to measure the actual electric resistance between two ALPOLIC panels of different distance. We also measure the resistance between ALPOLIC panel and the principal earth of the building. The result is shown in Table 2.

Table 2. Result of survey at actual ALPOLIC project

Measured points	Distance between two points	Resistance between two points
One ALPOLIC panel to another ALPOLIC panel	10m	0.2 ohm
	20m	0.3 ohm
	30m	0.2 ohm
One ALPOLIC panel to the principal earth of the building	10m	0.0 ohm
	20m	0.2 ohm

Fig. 4, ALPOLIC project where the survey was held

5. Difference between ALPOLIC panel and solid aluminum panel

Based on the same model mentioned above, the resistance of solid aluminum panel can be calculated as follows:

Table 3. Calculated electric resistance of solid aluminum panel

	Solid aluminum panel (aluminum 3.0mmt)	Sub-structure (steel, 100×50×2mmt)	Combined resistance of aluminum and steel
Specific resistance of aluminum and steel	4×10^{-8} ohm·m	10×10^{-8} ohm·m	-
Sectional area of metals in the model	$0.3m^2$ ($3.0\times10^{-3}\times25m\times4$)	$0.027m^2$ ($0.2\times2\times10^{-3}\times66$pcs.)	-
Electric resistance from top to bottom	0.13×10^{-4}ohm	3.7×10^{-4}ohm	0.13×10^{-4}ohm

From Table 1 and 3, the resistance of ALPOLIC external cladding can be compared with that of solid aluminum panel as follows:

	ALPOLIC	Solid aluminum panel 3.0mm
Combined resistance of aluminum and steel	0.66×10^{-4}ohm	0.13×10^{-4}ohm

Compared with the standard of 10ohm and the contact resistance of the junction points, both resistances are very small and the difference between two seems to be in a negligible range.