Aluminium systems profile selection

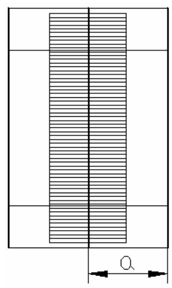
The purpose of this document is to summarise the way that aluminium profile selection should be made, based on the strength requirements for each application.

Curtain wall systems calculations

A. Column calculations

i) Moment of inertia formulae for the columns

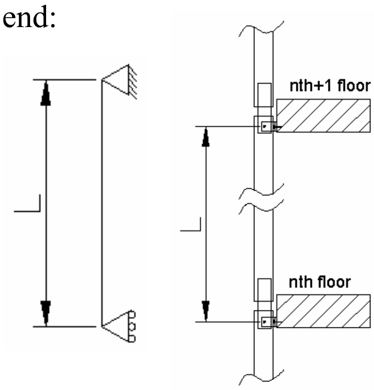
In Aluminium curtain wall systems, the choice of the profile to be used at a particular structure is based on the calculation of the required Moment of Inertia (MoI) of the aluminium profiles. The column must be stiff enough not to deform excessively when is subjected to the maximum design loads. The amount of column bending should be small enough to prevent the glazing to crack. The main loading of the columns is due to the wind pressure. It is assumed that each column is loaded by the force that half glass panel transmits to it on one side, and half glass panel on the other side, resulting in rectangular loading (see figure below). The columns can be supported in different ways, and the corresponding formulae for the Moment of Inertia (MoI) must be used during calculations. Here we will consider three different column support configurations:



→ In the following equations:
I : Required Moment of Inertia of the column (cm^4)
W : Wind load (kN/m^2)
L : Length (m)
E : Young's Modulus of Elasticity (GPa)
α : Distance between columns (m)
$F = \frac{L}{300}$, or 0.008m, whichever is smaller (glazing requirement-see below)

1. One end simply supported, with rolling support at the other end:

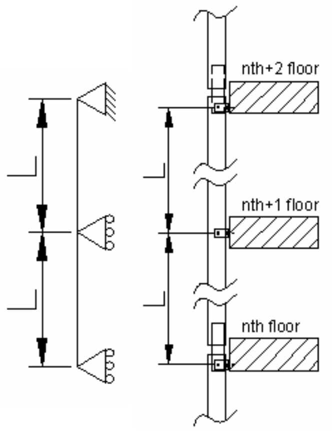
$$I = \frac{5 \times W \times a \times L^4}{384 \times E \times F} \times 100$$



This is the typical support case for curtain wall columns that span from floor to floor at a multistory building. The top end of the column can pivot around the screw that connects it with the structural bracket, and the lower end can slide on the insert that connects it with the column below.

2. One end simply supported, and rolling support at the middle and at the other end:

$$I = \frac{5 \times W \times a \times L^4}{922 \times E \times F} \times 100$$

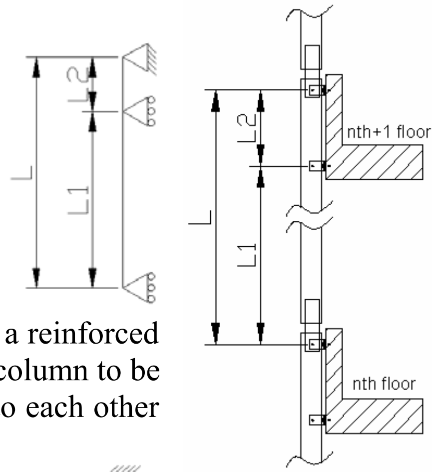


In this case we support the column with a support bracket at the middle, situated at the intermediate floor, if the column spans two floors. Alternatively the middle bracket can be fixed on a steel beam, mounted horizontally in the space between two floors. Note that the length L in this case is the distance between the support points and not the total column length.

3. One end simply supported, with a rolling support near the simple support, and a rolling support at the other end. Here we have two cases:

3.i. If $\frac{L_2}{L_1} \geq 0.2$

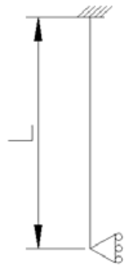
$$I = \frac{W \times a \times L_1^2}{384 \times E \times F} \times \left(9 \times L \times L_1 - 3 \times L^2 - 4 \times L_1^2\right) \times 100$$



This formula can be used in the case where there is a reinforced concrete wall section at each floor. This allows the column to be supported at three points, two of them being close to each other at the top, and one at the bottom.

3.ii. If $\frac{L_2}{L_1} < 0.2$

$$I = \frac{W \times a \times L^4}{185 \times E \times F} \times 100$$



In this case the upper end of the column is essentially fixed. This can be achieved using two brackets quite close to each other, or by using one bracket which is big enough to accommodate two holes and two mounting screws along the direction of the length of the column.

<u>ii) Value of wind pressure (W)</u>

The value of the wind pressure to be used in the calculations depends primarily on the height from the floor level where the curtain wall is situated. As a guideline, the wind pressure values with respect to the structure height are given in the table below:

Building height (m)	Wind Pressure (kN/m^2)
0 - 8	0.5
8 - 20	0.8
20 - 100	1.1

In some cases a correction factor must be used, to take into account specific environmental conditions. As a design rule, the wind pressure caused by a certain wind speed is given by the equation:

$$W = \frac{483 \times V^2}{10^7}$$

Where:

W : Wind load (kN/m^2)

V : Design (maximum) wind speed (km/hr)

iii) Allowable deflection (F)

To define the allowable deflection for our column, we must consider the type of glazing we are going to use:

a. If we are using single glazing

- $F = L / 200$, if $L < 3m$
- $F = L / 300$, if $L \geq 3m$

b. If we are using double glazing

- $F = L / 300$, and $F \leq 0.008$. This means that if the distance between the column support points is greater than 2.4 meters, we use F=0.008.

c. If we are using special glazing

- $F = L / 500$, and $F \leq 0.006$. This means that if the distance between the column support points is greater than 3 meters, we use F=0.006.

B. Transverse calculations

The transverse loading is mainly due to the weight of the glazing along the vertical direction, and due to the wind load horizontally.

i) Required glazing thickness

For single glazing, the minimum thickness is calculated using the following equations:

1) For $\frac{D_g}{D_s} \leq 3$, $e = \sqrt{\frac{1000 \times D_g \times D_s \times W}{72}}$

2) For $\frac{D_g}{D_s} > 3$, $e = \frac{L \times \sqrt{1000 \times W}}{4.9}$

In the above equations:

e : Minimum theoretical glass thickness (mm)

W : Wind load (kN/m^2)

D_s : The smaller glazing dimension (width or length) (m)

D_g : The greater glazing dimension (width or length) (m)

In case that a double glazing is the minimum total thickness of both glass panels will be equal to the minimum single glazing thickness multiplied by 1.5. For a Triplex glazing the minimum total thickness of both glass panels will be equal to the minimum single glazing thickness multiplied by 1.7.

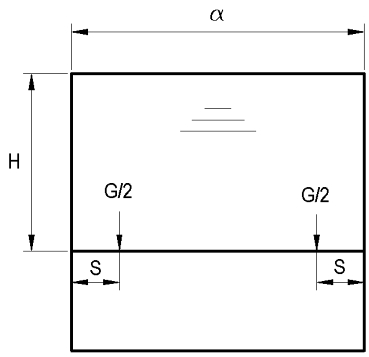
ii) Glazing weight

After selecting the glass thickness to be used, the total weight of the glazing can be calculated: we have 2.5kg per m^2 of glazing area per mm of glass thickness. For example, a 10mm thick glass (or a double glazing with 5+5 or 4+6 mm glass panels) will weight 25 kg per m^2.

iii) Moment of inertia formulae for the Transverse

The transverse is supported by two fixed supports at both ends.

- Bending in the vertical plane



The required MoI for the transverse for bending in the vertical plane (due to the weight of the glazing) is given by the equation:

$$I_y = \frac{G \times S}{48 \times E \times F_T} \times \left(3 \times a^2 - 4 \times S^2\right)$$

- Bending in the horizontal plane

The required MoI for the transverse for bending in the horizontal plane (due to the wind pressure) is given by the equation (fixed support at both ends):

$$I_x = \frac{W \times H \times a^4}{384 \times E \times F} \times 100$$

⟶ In the above equations:

I_x : Required Moment of Inertia of the transverse for bending in the horizontal plane (cm^4)

I_y : Required Moment of Inertia of the transverse for bending in the vertical plane (cm^4)

G : Total glazing weight (kg)

H : Glazing height (m)

S : Distance of the glazing support wedge from the transverse end (see figure); Typical value: $S = 0.15$m

a : Width of glazing (m)

E : Young's Modulus of Elasticity (GPa)

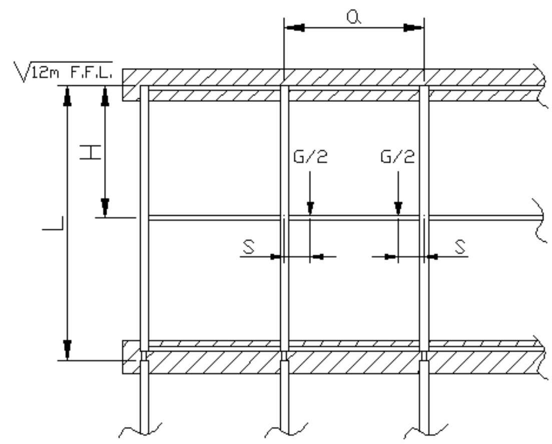
$F_T = \frac{H}{300}$, or 0.003m , whichever is smaller (glazing requirement)

$F = \frac{L}{300}$, or 0.008m, whichever is smaller (glazing requirement for double glazing)

D. Example of calculations

Column support configuration type 1 calculation example

Suppose we will construct an aluminium curtain wall, as shown in the figure below, with column length L=3m and distance between columns α = 2m. This will be installed at a height of 12m from the ground level, and have double glazing installed. So, we have:



Given:
L = 3m
α = 2m
W = 0.8kN/m^2 (from the table)
E = 70GPa (aluminium)
H = 1.5m
S = 0.15m
G = Total glazing weight (kg)
$F_T = \frac{H}{300}$, or 0.003m , whichever is smaller
(glazing requirement)
$F = \frac{L}{300}$, or 0.008m, whichever is smaller
(double glazing requirement)

We want to calculate:
I : Required Moment of Inertia of the column (cm^4)
I_x : Required Moment of Inertia of the transverse for bending in the horizontal plane (cm^4)
I_y : Required Moment of Inertia of the transverse for bending in the vertical plane (cm^4)

Column calculation:

We use double glazing, therefore:

$$F = \frac{L}{300} = \frac{3}{300} = 0.01$$, but 0.01>0.008, therefore we will use F=0.008m, and:

Type 1 column support - one end simply supported, with rolling support at the other end:

$$I = \frac{5 \times W \times a \times L^4}{384 \times E \times F} \times 100 = \frac{5 \times 0.8 \times 2 \times 3^4}{384 \times 70 \times 0.008} \times 100 = 301.3\,\text{cm}^4.$$

Hence, the required Moment of Inertia of the column for this construction is 301.3 cm^4. Based on this value, we can choose the column to be used. Say, for example, that we will make this curtain wall using ALUMIL M6 system. The appropriate column is M10919, with MoI I_x=507.18 cm^4, which is higher than the required MoI.

The calculation steps are identical for the other support configurations; only the formula for the MoI calculation is different.

Transverse calculation:

Selection of glazing

We have:
D_g=2m and D_s=1.5m, and:

$\frac{D_g}{D_s} = \frac{2}{1.5} = 1.333 < 3$, therefore we will use the formula:

$$e = \sqrt{\frac{1000 \times D_g \times D_s \times W}{72}}$$

From the wind pressure table, for height 12m, we must use wind pressure W=0.8kN/m^2. Hence:

$$e = \sqrt{\frac{1000 \times 2 \times 1.5 \times 0.8}{72}} = 5.77 \text{ mm.}$$

This is the minimum single glazing glass thickness that could be used. We want to use double glazed glass panels, so we must multiply this value by 1.5: e_{dg}=5.77x1.5=8.66mm. So, we decide to use 10mm total glass thickness for our double glazing, for example a 4mm glass+12mm gap+6mm glass glazing.

Glazing weight

The weight of our 4+12+6 double glazing panel will be:
G=(4+6) mm of glass x 2.5 kg per m^2 per mm glass thickness x panel area , hence
G=(4+6) x 2.5 x *H* x *α*=10x2.5x2x1.5=75kg

Transverse required Moment of Inertia calculations

- Bending in the vertical plane (due to the glass weight)
  $F_T = \frac{H}{300} = \frac{1.5}{300} = 0.005 > 0.003$, therefore we use F_T = 0.003m

The required MoI for the transverse due to the weight of the glazing will be:

$$I_y = \frac{G \times S}{48 \times E \times F_T} \times \left(3 \times a^2 - 4 \times S^2\right) = \frac{75 \times 0.15}{48 \times 70 \times 0.003} \times \left(3 \times 2^2 - 4 \times 0.15^2\right) \Rightarrow I_y = 13.3 cm^4$$

- Bending in the horizontal plane (due to the wind pressure)

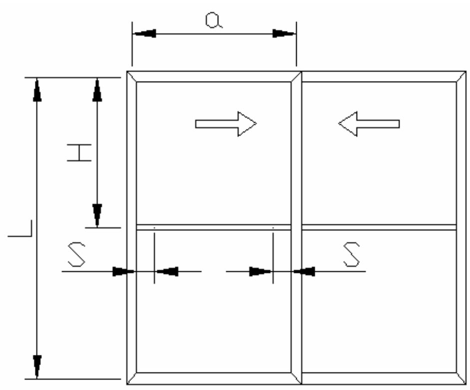
$F = \frac{L}{300} = \frac{3}{300} = 0.01$, but 0.01>0.008, therefore we will use *F* = 0.008m, and:

$$I_x = \frac{W \times H \times a^4}{384 \times E \times F} \times 100 = \frac{0.8 \times 1.5 \times 2^4}{384 \times 70 \times 0.008} \times 100 = 8.9 \text{ cm}^4.$$

Hence, the required Moment of Inertia of the transverse for this construction is I_y = 13.3cm^4 and I_x = 8.9. Based on this value, we can choose the transverse to be used. Say, for example, that we will make this curtain wall using the M6 system. We can use the M10911 transverse with MoI I_y=24.1 cm^4 and I_x=28.41 cm^4 which are higher than the required MoI.

Doors and windows systems calculations

Vertical members of sash



The appropriate formula to be used if we want to calculate the required MoI for the vertical members of a sliding door or window sash is formula 1, but α should be divided by 2. That is because we have simple support at the bottom and rolling support at the top, but the glass panel forces are applied to only one side of the sash profile, and not at both sides as is the case if a middle column of a curtain wall. So, the formula for the MoI becomes:

$$I = \frac{5 \times W \times a \times L^4}{2 \times 384 \times E \times F} \times 100$$

" T " profiles

For horizontal " T " profiles:

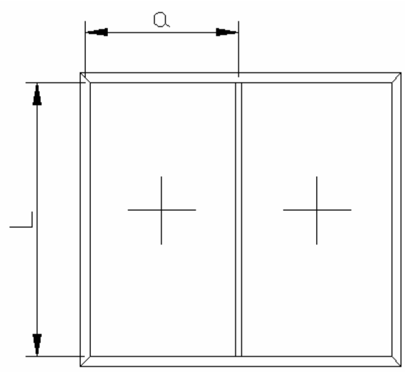
- Bending in the horizontal plane (due to the wind pressure)

$$I_x = \frac{W \times H \times a^4}{384 \times E \times F} \times 100$$

- Bending in the vertical plane (due to the glass weight)

$$I_y = \frac{G \times S}{48 \times E \times F_T} \times \left(3 \times a^2 - 4 \times S^2\right)$$

For vertical " T " profiles:



- If both ends of the " T " profile are fixed, we use the formula:

$$I_x = \frac{W \times H \times a^4}{384 \times E \times F} \times 100$$

- In some cases one end is fixed and we allow the other end to move (rolling support). This is done usually in big structures in order to accommodate the thermal expansion / contraction. In that case, the appropriate formula is:

$$I = \frac{W \times a \times L^4}{185 \times E \times F} \times 100$$