

PROJECT

One of the most difficult tasks of a designer is understanding the static functioning of door and window systems in order to assess the most common forces exerted.

The word "forces" indicates all external stresses that act on the window and deform it, thus increasing the internal stress of each single component.

Forces, or external stresses, are the wind pressure, the dead load and the incidental loads.

Wind pressure actually is not a "static" load because it constantly changes in intensity and direction. In the assessment of forces, though, it is considered as a constant element and taken in its maximum value.

The stresses exerted on a PVC frame must be separated into two different categories:

- transversal stresses (wind),
- stresses parallel to the frame plan (dead loads).

A clear distinction must also be made between the frame for windows and the frame for blinds.

In the first case, the most common forces are transversal stresses; in the second example, parallel stresses prevail.

Transversal loads

The window resists against the wind pressure and, like a sail that transmits to the mast the load it bears, the windowpane discharges the stresses exerted by the wind on fixed transoms and window posts.

The perimeter profiles of fixed frames can be considered stiff because they are fixed to the wall in different parts, but transoms and posts bend like a beam, placed on two supports, bends if a load is charged on it. The same applies to the profile assembly of the striker central knot in double-wing windows.

Also the profiles of mobile frames bend under the pressure of the wind that tends to pull them away from the fixed frame. Hinges and closing points or pawls, distributed along the perimeter, oppose to this action. The higher their number is, the less does the profile warp as it behaves like a beam placed on many different supports. Metal transoms are inserted in PVC profiles in order to limit the deformations and not to increase PVC mechanic strength that in most cases is absolutely sufficient. The level of deformations is obviously determined by the pressure exerted by the wind against the windowpane (kg/m^2), by the window dimensions, and also by the profile strength, with or without reinforcements.

Profile resistance

The mechanic strength (R) of a profile is the result of two concomitant factors, i.e. the elastic module (E) and the moment of inertia (J) of its section.

$$R = EJ$$

The mechanic strength, with the same (E) value, is directly proportional to the value of (J), e vice versa. The elastic module (E) is a characteristic of the material employed, and expresses its elastic changes under the stress exerted by traction or compression forces.

Each material has its own characteristic elastic module (tab. 4.1.2.A).

Density and elastic module of different materials employed in door and window systems.				
Materials	Density: g (kg/m ³)	Ratio to PVC	Elastic module: E (kg/cm ²)	Other materials
Anti-stress Pvc	1.400	1	28.000	1
Wood (spruce)	800	0,57	100.000	3
Pultruse	1.850	1,32	200.000	7
Concrete	2.500	1,8	300.000	11
Aluminium	2.700	1,9	700.000	25
Steel	7.850	5,6	2.100.000	75

Tav. 4.1.2.A

The moment of inertia

The moment of inertia (J) is a characteristic of the profile section's geometric shape and expresses its flexural behaviour, independently of the material of which the profile is made.

Profiles having the same section and the same geometric shape have the same moment of inertia (J), even if they are made of different materials. J is assessed in cm⁴.

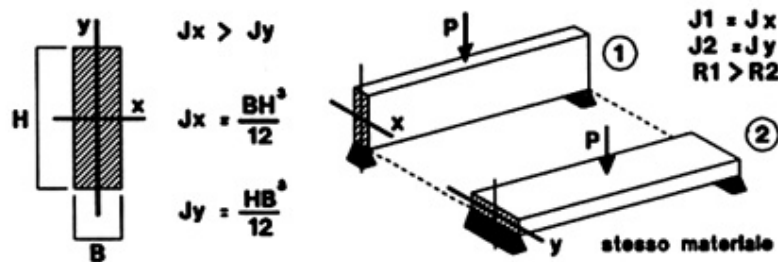
Usually, two moments of inertia are calculated:

- One with reference to the horizontal barycentre line X;
- One with reference to the vertical barycentre line Y.

The moment of inertia that quantifies the strength (from the geometrical point of view) of a profile is the one calculated with reference to the barycentre line at right angle (i.e. 90°) with the stress direction, or pressure, exerted by wind.

To make an example, a profile having a full rectangular section, will have a higher moment of inertia calculated with reference to the right-angle barycentre line that cuts the minor sides (the section area is the same, but the distance from the barycentre axis is different).

The Table 4.1.3.B, illustrates from the mathematical point of view, the obvious concept that a beam laid on edge has a greater resistance than a beam positioned horizontally.



Tav. 4.1.3.B

If two profiles are made of different materials the calculation of the moment of inertia is not sufficient to assess which is the most resisting but a comparison of the two (R) values, obtained by multiplying the two (J) values with the two (E) values, must be made, i.e.

$$R1 = E1 J1$$

$$\text{with } R2 = E2 J2 \text{ (Tav. 4.1.3.C)}$$

$$EA = 200.000 \text{ Kg/cm}^2$$

$$EB = 600.000 \text{ Kg/cm}^2$$

$$Jx1 = 15 = Jx2 \text{ cm}^4$$

$$Jx3 = 40 = Jx4 \text{ cm}^4$$

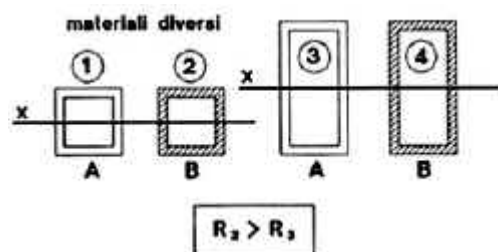
$$R = EJ \text{ Kg} \cdot \text{cm}^2$$

$$R1 = EAJx1 = 3 \times 10^6 \text{ Kg} \cdot \text{cm}^2$$

$$R2 = EBJx2 = 9 \times 10^6 \text{ Kg} \cdot \text{cm}^2$$

$$R3 = EAJx3 = 8 \times 10^6 \text{ Kg} \cdot \text{cm}^2$$

$$R4 = EBJx4 = 24 \times 10^6 \text{ Kg} \cdot \text{cm}^2$$



Tav. 4.1.3.C

More specifically, the variables that determine the choice of certain kinds of reinforcements are the following:

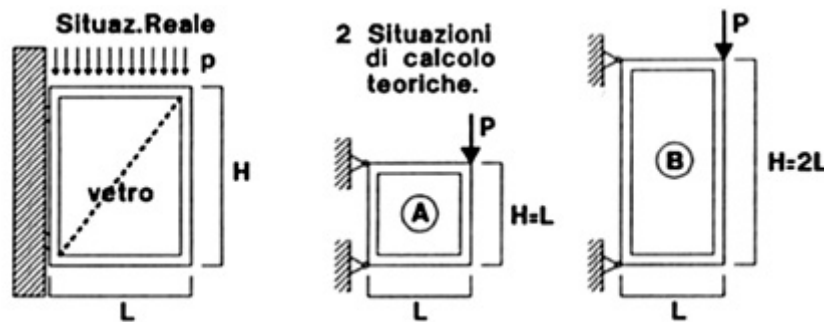
- Wind pressure: V [kg/m^2]
- Its linear load: q [kg/m]
- The elastic module: E [kg/cm^2]
- The moment of inertia: I [cm^4]
- The window dimensions: L, H [cm]
- The distance between the closing points: A, B, C [cm]

Coplanar loads

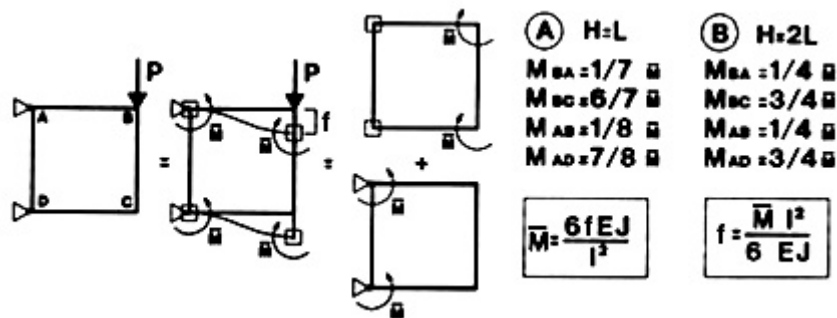
With reference to stresses exerted by dead loads, the windowpane is an excellent stiffening element for overhung wings (as in the case of windows).

Let us think about examples where there is no windowpane though (like in the case of blinds) and that the four sides of the mobile frame are made with the same profile and internal reinforcements.

If we calculate for the two examples $H=L$ and $H=2L$ shown in Table. 4.1.4.A, the internal flexural stresses, caused by a load placed on the outmost frame angle, the result is that vertical sides (AD and BC) undergo greater stress, 3 to 7 time higher, than horizontal sides (AB and DC). Tab. 4.1.4.A (Real situation, windowpane, theoretic calculation)



Tav. 4.1.4.A



Tav. 4.1.4.B

This demonstrates that a PVC blind mobile frame should be stiffened, at least its vertical sides, in order to increase the resistance against dead loads.

The reinforcements of Alphacan blind profiles are connected to each other through:

- The insertion of appropriate resin printed pieces that increase the sealing area of the angle
- The insertion of special stainless steel squares into the appropriate profile chambers

thus increasing the resistance against these loads and reducing the stress exerted against sealed.

This system enables to realise PVC blinds with large wings, as can traditionally be found in the historical cores of Italian cities, that are safe and do not warp.

As far as incidental loads are concerned, there are different loads that can incidentally exert pressures against windows and cause internal stresses, which can actually be considerable.

These include the "wrong manoeuvre", i.e. the inaccurate actions of users that sometimes do not follow the instructions given by suppliers, or due to production shortcomings.

In all these cases windows should not break, warp or be spoilt from the aesthetic point of view and their functionality should not be permanently damaged.

Other dynamic incidental loads include impacts, i.e. stresses that are rapidly exerted but rapidly removed. A window that adequately resists against wind pressure will certainly resist against this kind of loads as well.