RESEARCH HIGHLIGHT

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Design of Durable Joints between Windows and Walls

INTRODUCTION

The joints between windows (or doors) and the structure of buildings are without doubt the most delicate and the most vulnerable. All too often, this is where the first signs of deficiencies in the building envelope appear. Poorly designed and prepared joints, which mean improperly installed doors and windows, can cause several major problems. These include:

- infiltration and exfiltration of air and sound
- condensation which can result in toxic molds and cause major degradation of the envelope
- rain seepage
- reduction in insulating capabilities
- discomfort
- increase in heating costs
- deterioration of interior finishings

The quality of window installation ranges quite significantly from one site to another. The essential nature of the wall air barrier system, particularly the connection between windows and the structure itself, is often misunderstood and improperly incorporated by building designers and builders. However, if the Canadian window installation standard (CSA A440.4) published in 1998 is followed, effective joints can be designed to last for the effective useful life of the building envelope, for example, for more than 25 years. It would certainly be in the interest of window manufacturers, building designers and even window installers to obtain a copy of this document, which is about 100 pages long, to offer better service to their customers. Though there are general principles which apply, including air barrier integrity, there is no easy and universal method of installation that applies to all types of windows.

RAIN BARRIER

Before we begin, it is important to point out that face- sealed walls are to be avoided, because in that case, the joints must always be perfect to keep the rain out. This is physically impossible. The rainscreen wall is superior by far: it has an air space behind the outer covering which allows rain and humidity to run behind it and out through openings in the lower portion. This wall must have two joints - an outer joint to keep rain out of the cavity and especially, a perfectly sealed joint to the inside. This inner joint is necessary to keep air and humidity from getting into the wall and ensure that pressure in the cavity is the same as that acting on the outside of the wall. In addition to reducing heating costs and preserving the effective resistance of thermal insulation around the perimeter of the window, this interior joint reduces the risks of condensation on the window frame. The additional cost of the rain barrier is largely recouped by avoiding maintenance and repairs to the wall. The interior joint is very durable, as it is protected from sun and other sources of wear.

To summarize, the quality of design and the application of details are essential to the long life of the envelope, including in particular, the top flashing, the mastic joint itself, the continuity of the air barrier and evacuation of condensation moisture. The flashing, which sits on top of a window, gathers water in the wall cavity and directs it outside the siding. It prevents water from building up on the top of the frame and trickling down toward the studs or even into the building. Always select materials that stand up to the rigorous action of the mason's trowel.

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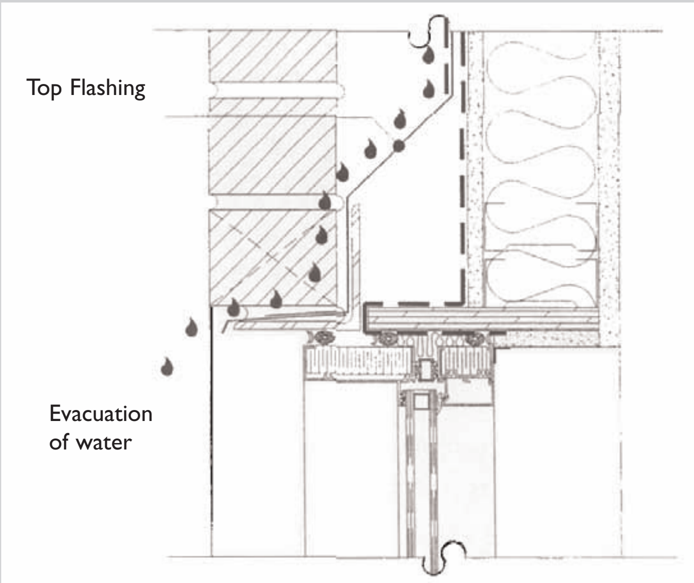

Figure 1 Top Flashing

THE PERIMETER JOINT

For application, the ideal ratio between the width of the joint and the depth of the mastic product is about 2 to 1, but the depth must always be between 3 and 12 mm. It must be at least 9.5 mm wide (3/8"), because a joint that is too thin has a tendency to crack in the winter when the window shrinks. The optimal width of the joint depends on several factors:

- differential movements between the frame (the fixed part) of a window and the wall;
- the construction tolerances (the inaccuracy of field measurements) of a pre-frame or the building shell. The materials used for a wall prefabricated in the plant require a very small tolerance as compared with cast-in-place concrete.
- manufacturing and installation tolerances of doors and windows (the differences of the measurements can vary between 1.6 mm and 3.2 mm, if the frame is somewhere in the area of 1,830 mm);
- elasticity of the caulking mastic.

The expansion (heat) and the shrinking (cold) of a window mainly depend on the dimensions of the window, the nature of the materials used, temperature variations and surrounding humidity levels.

COEFFICIENT OF LINEAR THERMAL EXPANSION

Material	Expansion coefficient (in mm/mm/degrees C x 106)
Wood	6.5
Brick	5.6 to 6.3
Concrete	11.7
Steel	12
Aluminum	23.2
PVC	40 to 80
Fiberglass	5.4

For large openings (for example, 2 m x 2 m) in a wood-frame structure, the potential dimensional variation will always be less than .55 mm, which is negligible. However, the play significantly varies depending on the additives used in the various types of PVC. The manufacturer must therefore be asked about the expansion coefficient for each type of PVC.

For example, since movement in PVC frames is three times more than aluminum and 10 times more than wood, the width of the perimeter joint must vary according to the material used in the window frame and the building shell. Despite this, on work sites the joints are usually constructed with the same width, which causes deformations with temperature changes. For example, a wave in a window sill can be caused by swelling in the summer, due to a frame joint that is too narrow.

CHOOSING A MASTIC

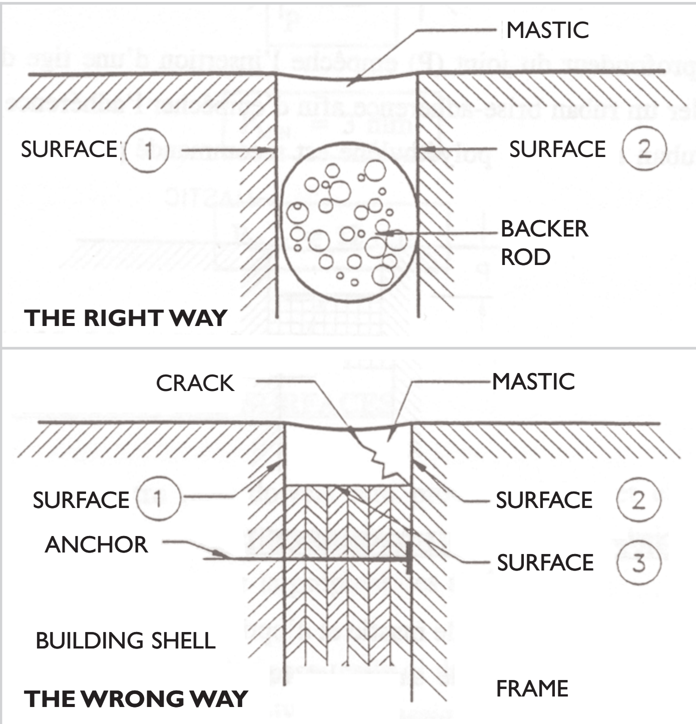

Figure 2 Shimming and Anchoring a Casement Window

The most important property of a mastic is elasticity, followed by its degree of adhesion, its resistance to the passage of air and its water vapour permeability. To avoid cracking, the mastic must only adhere to both lateral surfaces to the joint, not to the bottom surface. A backer rod, such as a polyethylene strip whose initial compression during installation will be 25 to 35 per cent must be used to avoid subjecting the mastic to tension created by its adherence to a third surface. A polyethylene tape can be inserted when the depth of the joint rules out the use of a strip.

The capacity of the mastic to withstand cyclical movements is expressed by its EMAX rating. Mastics are usually classified based on the percentage of joint extension and compression (from 5 to 50 per cent), without failure. The calculations required to obtain these tolerances are presented in the appendix of the full version of this report: Classification of the performance of mastics based on maximum elongation permissible (EMAX) subject to the effect of alternate dimensional variations.

Elongation Capacity	anticipated differential Movements (%)	Examples of mastics
low	5	Oil- or resin-based, latex
Average	5 to 10	Acrylic, butyl, neoprene, vinyl, latex
High	10 to 25	polymer captan, polysulphide, polyurethane
Very high	25 to 50	Silicone

SIZING JOINTS

Case studies were used to calculate the optimal size of joints for all types of doors and windows. The minimum and maximum dimensions of joints are dictated by the CSA A440.4 window installation standard on the basis of their esthetic acceptability. For example, we have presented hereunder the results for a 1,000 mm x 1,600 mm (39,4” x 63”) sliding window made of various types of materials (wood, PVC, aluminum and fiberglass). The window is installed on the ground floor of a new wood-frame building with aluminum or PVC clapboard siding in Montréal. For this particular window, the lateral joints can vary between 9.4 and 19 mm, and those between the sill and the top between 12.5 and 22 mm. The designer must design the optimum size of the joints based on the movement properties of the mastic selected.

Using the same sliding window as an example, the following are the results for a mastic with 10 per cent movement capacity:

Fittings	Joint Width	Specified Opening
Wood	3 mm	1,019 x 1,625 mm
Aluminum	15 mm	1,033 x 1,633 mm
Fiberglass	15 mm	1,030 x 1,630 mm
Average PVC (60 x 10-6 mm/mm/°C of linear expansion)	29,9 mm (exceeds the maximum of 22 mm called for in the standard)	1,030 x 1,630 mm

For this PVC window, the width of the required joint exceeds the maximum of 22 mm in the CSA440.4 standard. A mastic with a greater movement capacity (for example, 20, 30 or 40 per cent) will have to be selected.

Fittings	Joint Width	Specified Opening
PVC and 20% mastic	16.5 mm	1,033 x 1,633 mm
PVC and 30% mastic	12.5 mm	1,025 x 1,625 mm
PVC and 40% mastic	10 mm (sides) and 12.5 mm (top and bottom)	1,025 x 1,620 mm

SHIMS AND ANCHORS

The placement of shims is critical. Since most doors and windows sit on shims when they are installed, the differential movements will initiate at the shims on the sill of the frame. For fixed windows which come with setting blocks, the shims themselves are installed in the same location. On the sides, if the shims are placed too close to the corners, they will block any expansion caused by summer heat. The window will push on the studs, the sill will swell and may even cause the corner to rupture. On the posts in all four corners, the first shim must be inserted a minimum distance away from the corner, depending on the materials used, for example, at least 200 mm for PVC and 50 mm for wood. The maximum distance between the middle shim and those in the corners must not exceed 600 mm for PVC and 800 mm for wood. In general, unless the manufacturer indicates otherwise, a shim shall not be placed at the top of the window, which would restrict upward movement when the window expands.

Before anchoring the window in place, ensure that the exterior glass is lined up with the wall insulation and not outside it, to keep it as warm as possible. In addition to maximizing comfort and limiting home heating costs, warmer glass is less likely to be the target of condensation.

Then comes the anchoring of the window. Only secure it at as few locations as possible to keep water from seeping in through the screw holes. In principle, unless the manufacturer recommends otherwise, the top of the window will not be anchored to allow upward movement and to avoid transferring the weight to the lintel. The latter carries the load over the window, but the window must not support it. Along the sides, the window is anchored into the shims with screws or metal strips, never with nails. PVC is secured with hinged anchors, which allows for significant movement. For the sills, anchors can be dispensed with, provided the window does not exceed 1,600 mm for PVC (consult with an engineer if it exceeds 2,400 mm). Sill anchors are required when the window exceeds 2 to 3 metres, whether wood, aluminum or fiberglass. Consult with the manufacturer.

Standard A440.4 contains figures and tables, showing the ideal positioning of shims and anchors for the installation of all types of doors and windows.

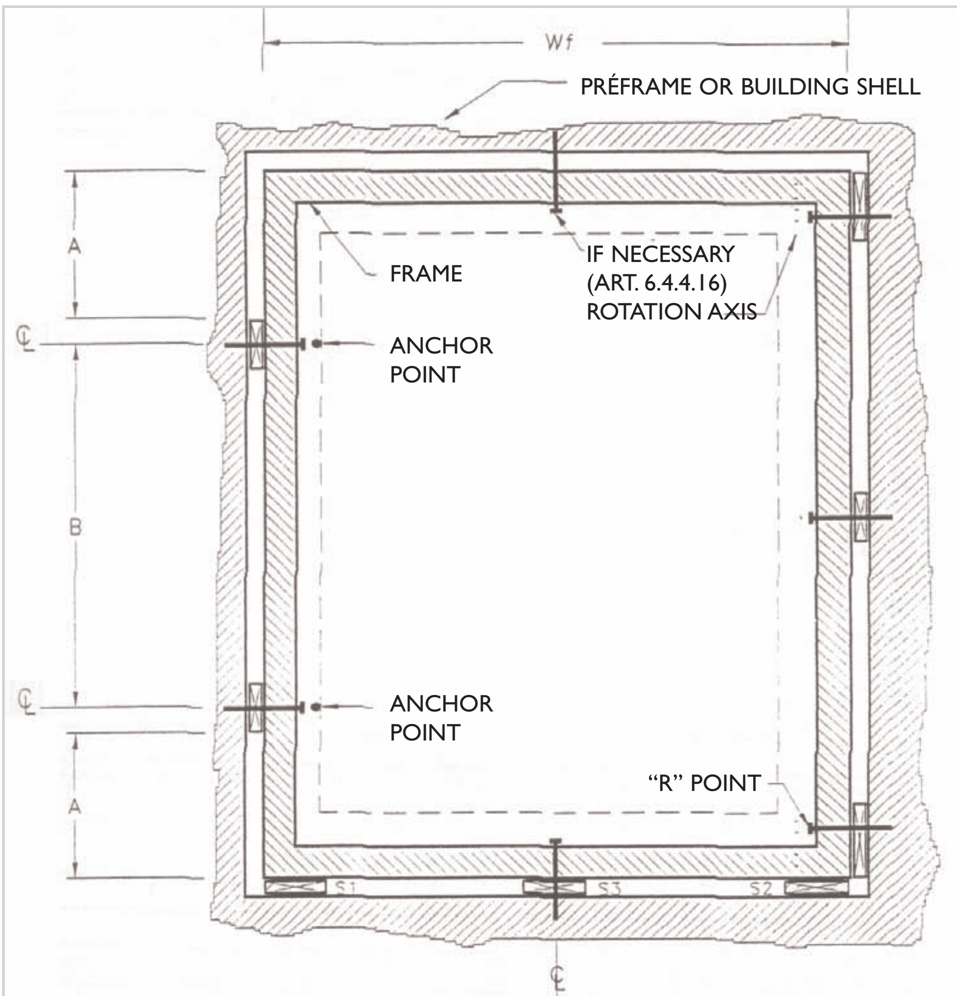

Figure 3 Shims for Casement Windows

INSULATION

The thermal insulation in the space between the building shell and the window has an important function in a sound joint. When fibreglass is used, it should not be compressed into a crack, which will lessen its insulating capability. Above all, the insulation function must not be confused with airtightness or water vapour tightness. Insulation partially obstructs air flow, but it does not achieve the desired level of airtightness.

The air barrier must be continuous, whether it is placed on the inside or the outside of the wall, such as applying the air barrier material to the inside of the window. For example, use a self-adhesive membrane or a polyolefin (a watertight air barrier material) and glue it on to make the window airtight.

Note that polyurethane foam acts as insulation and an air barrier, but to do so, it must be permanently stuck to the window. In general, this product is not recommended with PVC or aluminum fittings, because cracks will appear, either due to a lack of adhesion (consult with the manufacturer) or because the insulation will not follow the contraction of the window in the winter. The foam must be easily compressible and extensible to ensure long-term adhesion. Moreover, to avoid causing deformations in the frame when the swelling foam cures, it must have a low expansion coefficient and be applied in two thin coats. Finally, since polyurethane is water impermeable, avoid using it on a wooden sill, which could rot if water were to accumulate. It is also wise to slant the sub-sill outside so that gravity can drain water build-up.

In conclusion, bear in mind that sound joint design is essential to achieving the best possible installation of windows and that the manufacturer's recommendations must always be followed to obtain optimal resistance from the mastic, which will protect the building envelope over the long term.

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Consultants for the Research Project: Air-Ins Inc. and Groupe Petrone, 1999

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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