TALAT Lecture 2104.02

Building Products - Windows

Aluminium Windows

18 pages, 18 figures

Basic Level

prepared by Carsten Dreier, Hydro Aluminium, Oslo

Objectives:
- To give teachers and students a grounding in the development of satisfactory and suitable window design in aluminium and
- to help them acquire an understanding of the principles underlying good design.

Students need to be able to design aluminium windows which conform to local planning regulations and which are suitable for national traditions in each market they are offered in. This involves the acquisition of local climatic data since the products need to withstand the climatic conditions pertaining in the different marketing zones. Products need to be of a design acceptable to architects and must also fulfil the requirements of the market.

Prerequisites:
- basic design engineering background
- basic knowledge of corrosion effects
- TALAT lecture series 2100, 2200 and 5104

Date of Issue: 1994

2104.02 Building Products - Windows

Table of Contents

Climatic Problems and Requirements

The greatest climatic problems affecting the design of outer walls in general are:

- Driving rain
- Wind damage
- Wind causing draughts
- Temperature differences causing loss of heat
- Variations in temperature

Driving Rain

Driving rain is one of the main causes of widespread damage through damp, not in the metal frame itself but in the surrounding walls unless the window is so designed as to keep the rain out even under the most extreme conditions.

Climatic conditions vary of course in different parts of the world, and national standards as a rule take local weather conditions into account as regards annual rainfall, average wind speeds and air temperature experienced. The quality of the product must therefore always be in accordance with the standards set. A window in Northern Europe will consequently be designed differently from one to be used in the Mediterranean region.

Wind Damage

High velocity winds can cause great damage to buildings, and window profiles must be designed to have a rigidity and a strength which can resist any distortion whether temporary or permanent which wind could possibly cause. There are methods of calculation and computer programs which permit to determine the maximum height and width of a window for the various profile types dependent on the wind strengths which occur locally.

Wind Causing Draughts

Differences in pressure on window structure caused by wind can lead to draughts through the structure with consequent loss of energy from the building. Most countries have imposed their own requirements for draught-proofing windows, again depending on the local climatic conditions, and in most cases the draught proofing of windows must be documented by means of laboratory tests before it can be marketed.

Temperature Differences Causing Loss of Heat

A window of pure aluminium will have relatively high heat conductivity. In zones with cold winters it will thus be necessary to reduce conductivity in the structure by using two profiles with an insulating layer in between: a window with a so-called broken cold bridge. The insulator must in addition have a strength which makes a solid connection between the two profiles.

Variations in Temperature

Thermal expansions within an aluminium window tend to be relatively large with a spread of 0.024 mm/m per °C. For windows of normal size this will be of little importance as regards stability and imperviousness. But when installing the window in the wall these temperature variations must be allowed for by making a flexible connection. For larger windows split joints should be used, which can absorb the changes in temperature without spoiling the seal.

All the conditions mentioned will have an influence on the design of the product and we will return to this in later sections.

The Metal itself and its Characteristics

Aluminium is produced in alloys of various strength levels, depending on the use to which it is to be put. For building purposes alloy AlMgSi0.5 (AA6060) is normally used.

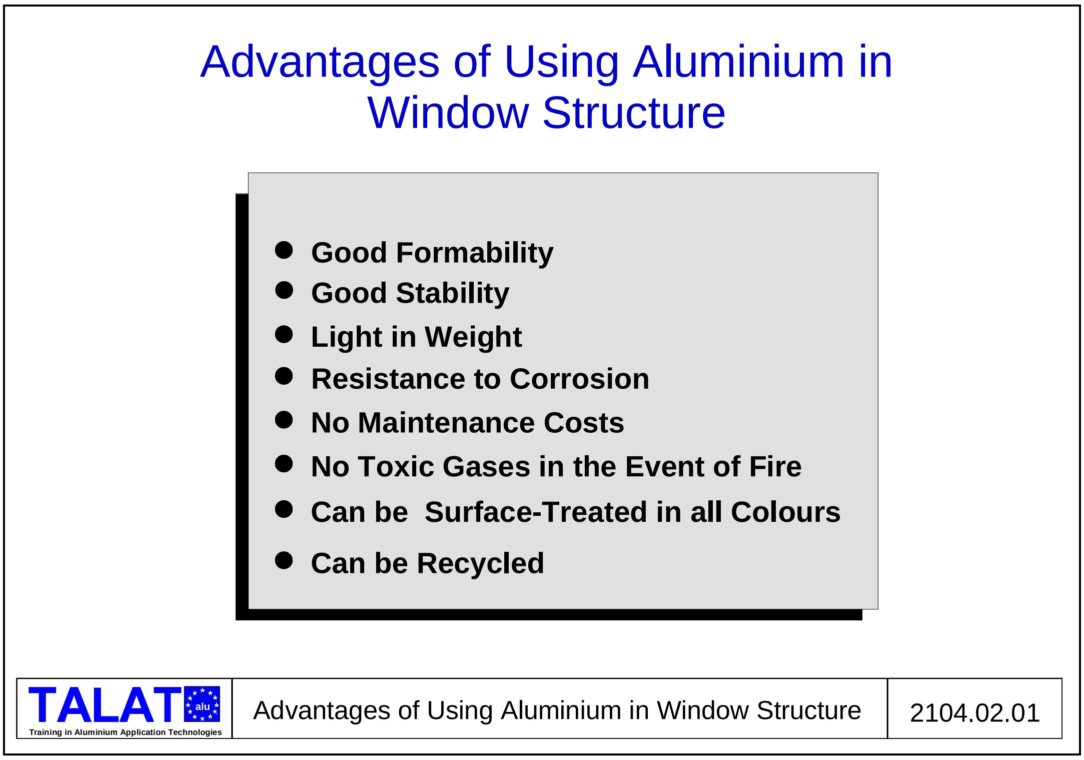
Aluminium can be easily worked in different ways in both a hot and cold state. Inasmuch as the metal, when prepared, is easy to cut, stamp, saw, mill and weld, it is an excellent substance for building purposes. The fact that the metal is also resistant to corrosion and allows surface treatment in several ways makes it especially suitable for use in outside walls and particularly for windows and doors.

Aluminium Profiles for Windows

Aluminium profiles are made by an extrusion process where the metal is melted and forced through a jet to a profile of the desired cross section. The coherent length is cut off, stretched and toughened and then goes for further treatment depending on the purpose. By means of extrusion the desired profile shape can generally be attained, thus preserving rigidity and strength, and allowing a profile shape suited to the window's function and also providing resistance to external climatic stress.

The advantages of using aluminium for the manufacture of windows can be summed up as follows (**Figure 2104.02.01**):

Good formability
Good stability
Light in weight
Resistant to corrosion
No maintenance costs
No noxious gases in the event of fire
Can be surface treated in all colours
Can be recycled



The only possible weakness resides in the high thermal conductivity and also in the fact that the costs of an aluminium window are somewhat higher than those for windows in alternative materials such as wood and UPVC. However, if one takes into consideration production and maintenance costs over a period of time, aluminium windows are definitely economical.

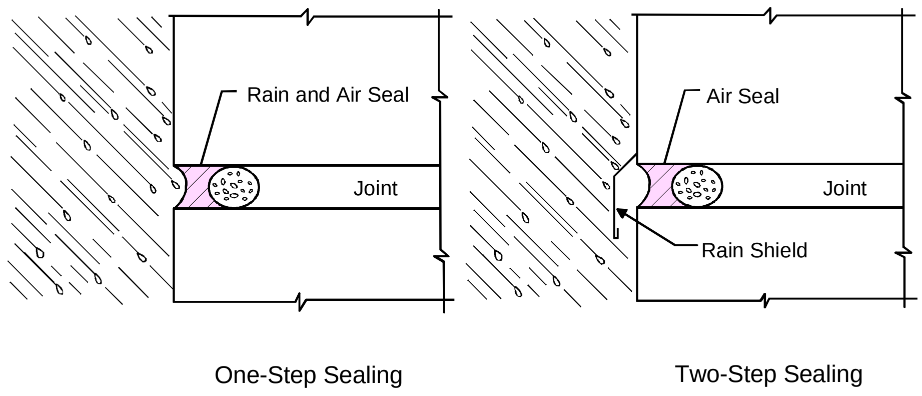
The Principles of Good Window Design

In order that a façade or its components such as windows may be able to resist the stresses to which wind and weather expose them, windows must include in their design certain characteristics which make them sufficiently resistant to:

- rain, especially driving rain, to prevent leakage and damage caused by damp
- wind, to prevent draughts and reduced insulation efficiency
- wind damage, to prevent sections falling or being torn off.

It is thus especially important for windows to be designed precisely with these factors in mind. This requires that they be built on the lines of two-stage sealing (**Figure 2104.02.02**).

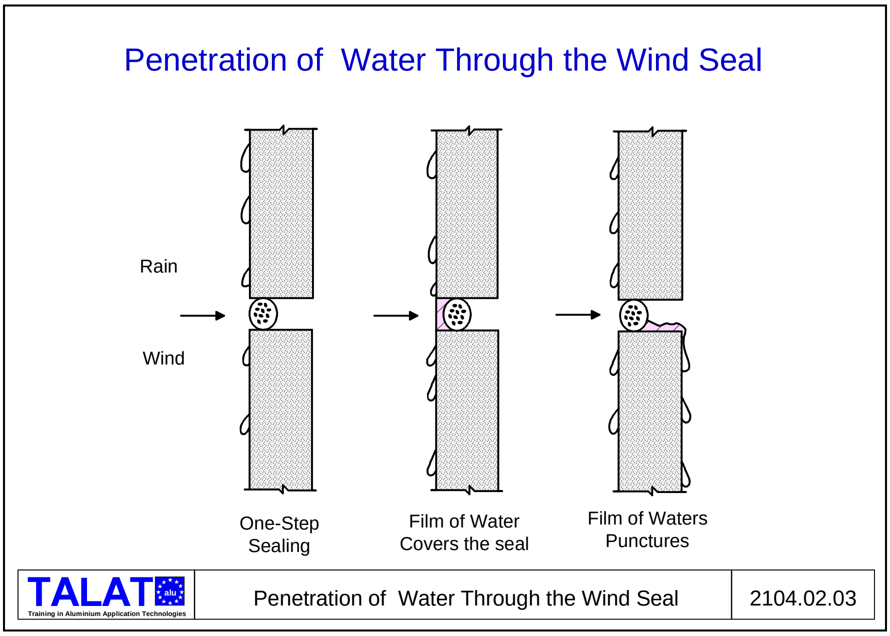
Principle of Two-Step Sealing



TALAT	Principle of Two-Step Sealing	2104.02.02

Two-stage sealing means that the construction has an outer rain seal or protective guard (first stage) and an separate inside wind seal (second stage). The rain shield should as far as possible prevent rain from penetrating the structure and coming into contact with the most important part of the window, i.e. the wind seal. The total pressure difference between the outer and inner side of a building under wind stress will always be above the wind seal itself in the wall or windows. Should the wind seal get wet by rain, the pressure difference will be on the film of water covering the wind seal.

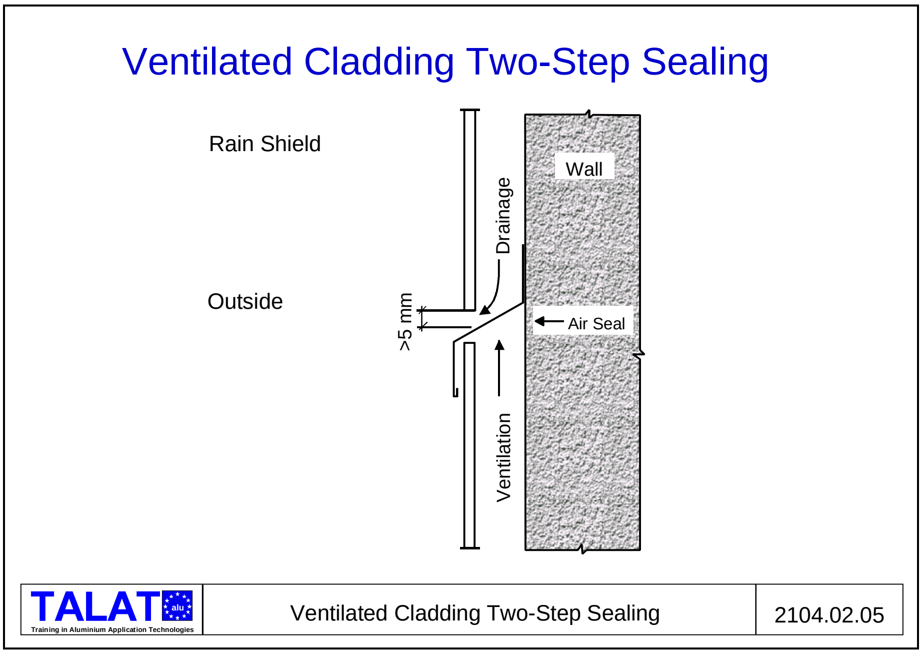
This film has no strength to resist the fall in pressure and will rupture at the weakest point in the wind seal itself. Water leakage is thus almost guaranteed through the wind seal and thence into the wall or towards the inside of the window (**Figure 2104.02.03**). Provided the rain does not come into contact with the air seal - which in an opening window is always a strip of rubber-based material - no such leakage is likely to occur. A gap between the rain- and air-seals which is also drained and ventilated will form a pressure equalising chamber, hence reducing the air pressure on the wind seal.



Windows, both opening and fixed, must therefore always be designed such that (**Figure 2104.02.04**):

rain must never come into contact with the wind seal.

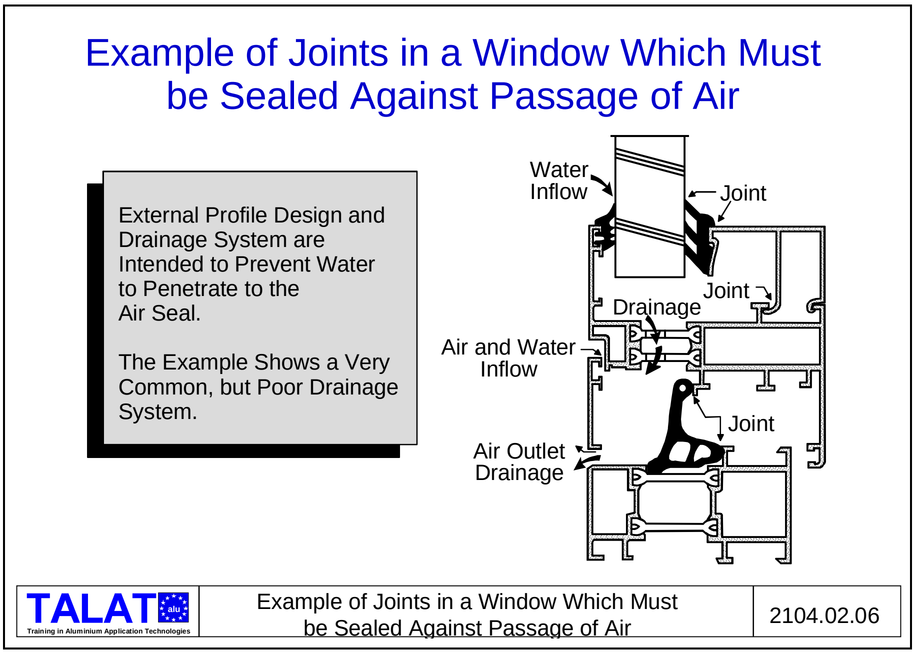
This principle has been introduced for façades in Curtain Walls and other similar designs with extremely good results in the main, but not introduced totally in the design of windows and doors, where some damage has occurred (**Figure 2104.02.05**).



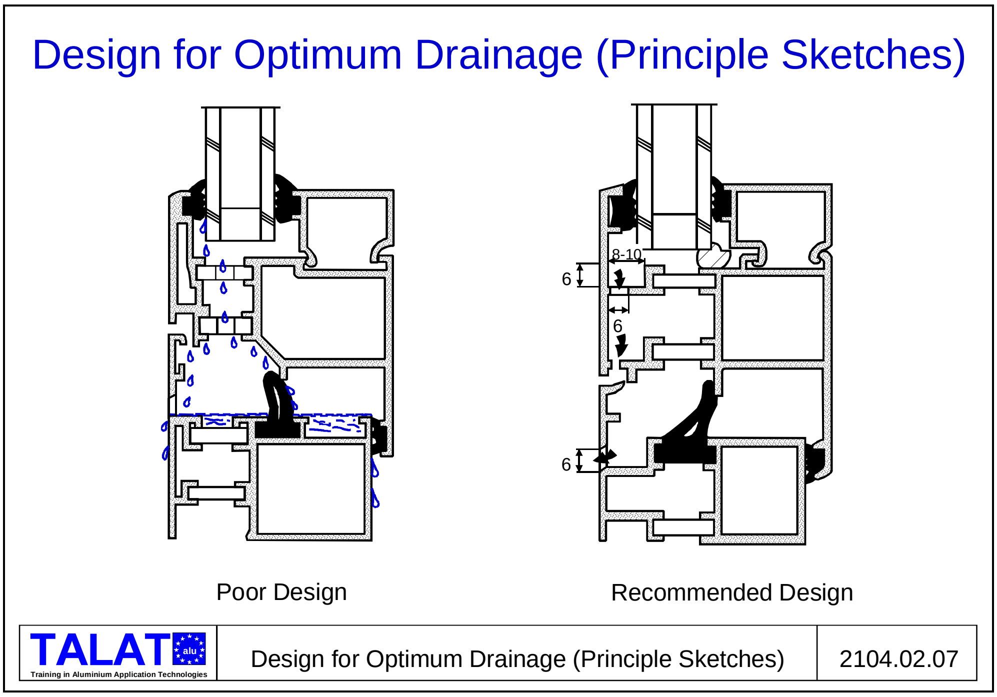
Drainage

A window has several types of joints which must all be supplied with two-stage sealing. These are joints between glass and sash, joints between sash and frame, joints between glass and any crossbars, and for fixed windows, joints between glass and frame.

One should always bear in mind the fact that during periods of simultaneous wind and rain some water will pass the outer rain shield both between the window sash and frame and into the glass rebates. The space behind the shield must therefore be equipped with a drainage system which conducts the water out to the exterior again before it comes in contact with the air seal (**Figure 2104.02.06**).



Generally speaking, the drainage system will consist of a collection channel on the sill and lower window profile, which must have a minimum dimension. Likewise the drainage holes which will conduct the water away, should have a minimum dimension (**Figure 2104.02.07**).

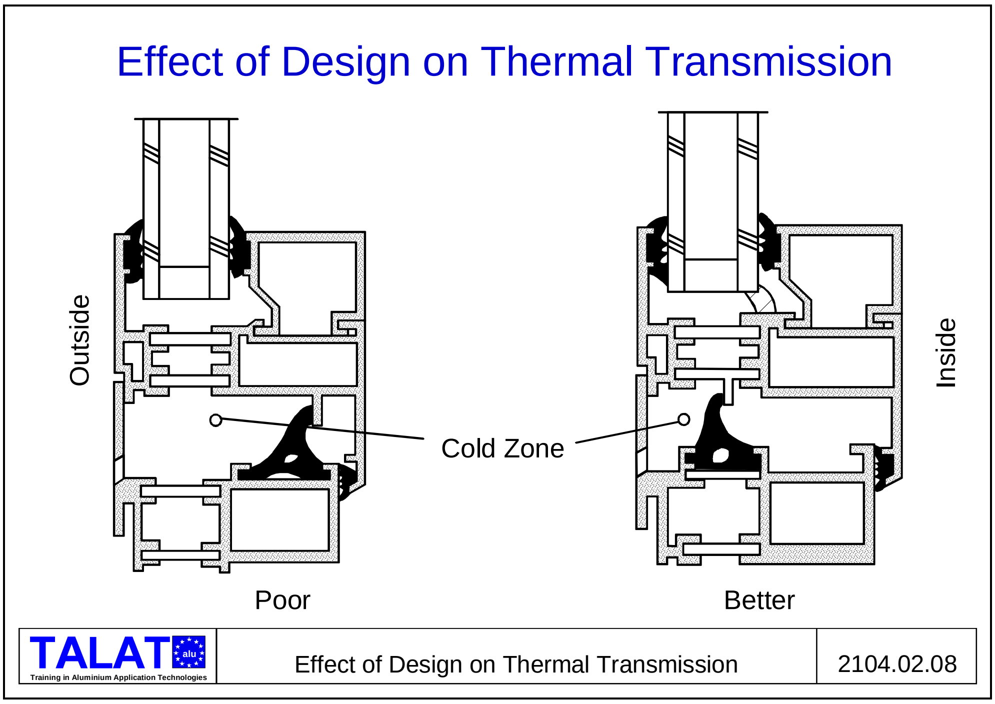


The dimensions are determined by the size of a water drop which is approximately 4.5 mm in both the horizontal and vertical planes. A drainage channel or hole must therefore be larger than 4.5 mm such that the surface tension in the drop does not cause it to adhere to the sides of the channel or holes, and thus prevent satisfactory flow before it has built up a water level within the channel which then may push the water towards the air seal.

It is recommended, therefore, that the collection channel should have a width and height of 5 mm minimum and that drainage holes should also be 5 mm minimum in diameter. A drainage slot of e.g. 5 x 10 mm is better than a round hole.

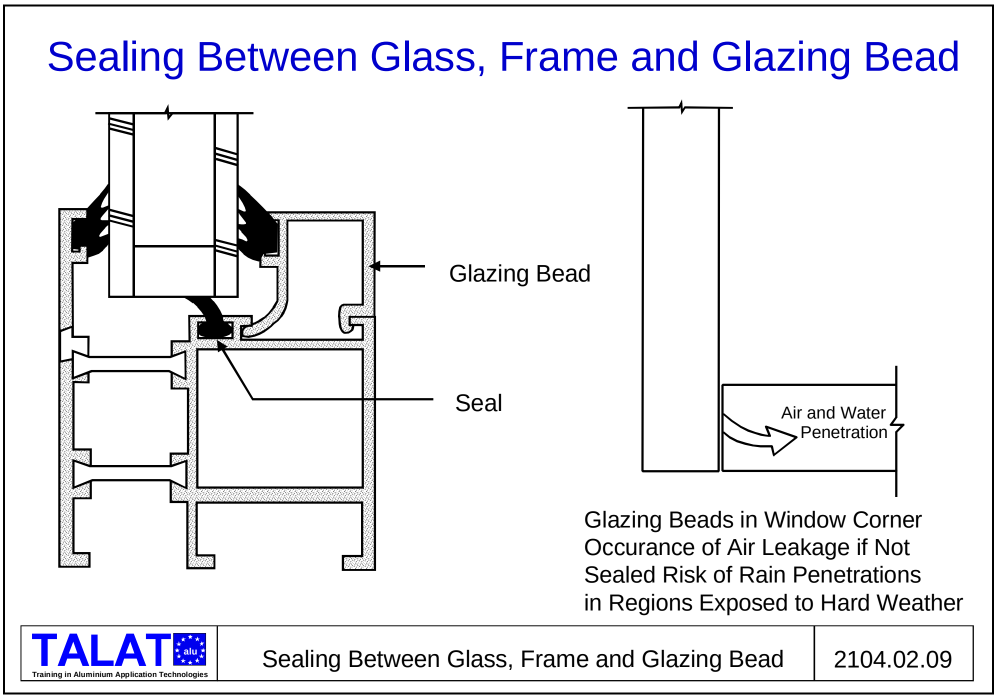
Air sealing

Air seals both round the glass and between the frames consist today of rubber or plastic based strips. These are fed into tracks in the aluminium profile and are placed differently dependent on the type of window. A central seal between sash and frame is most often used, as it improves the structure's thermal characteristics at the same time by stopping outside air at the exterior part of the structure. It is normally at the corners where problems arise and it is therefore vital to seal the corner joints either by gluing or welding the strips. Sealing round the glass is normally accomplished by cutting off the strips slightly overlong and pressing firmly together in all corners. This appears to be a sufficient and rational solution **(Figure 2104.02.08)**.



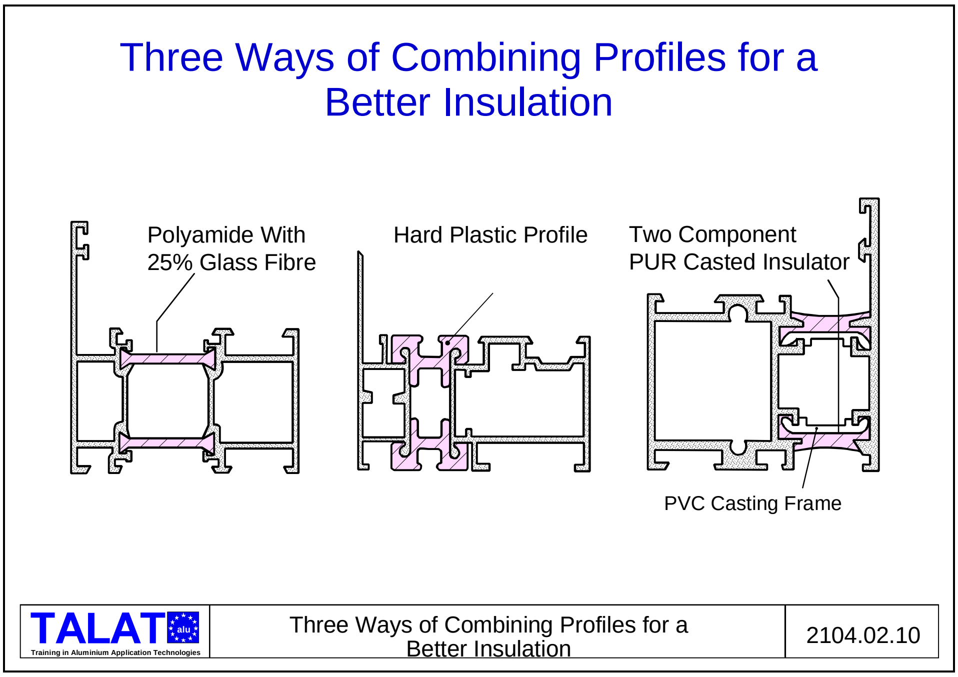
In regions which are especially exposed to wind it can be a good idea to lay in a seal in a rebate between glass and frame as aluminium windows usually have internal glazing beads which can never be completely sealed where they abut each other in the corners. The glass must thus be sealed all the way round (**Figure 2104.02.09**).

.



Insulation

For windows in low temperature zones insulated window systems are necessary for part of the year in order to reduce heat loss from the building and the risk of condensation. There are three different ways of effecting such a combination of two profiles into one structural unit **(Figure 2104.02.10)**.

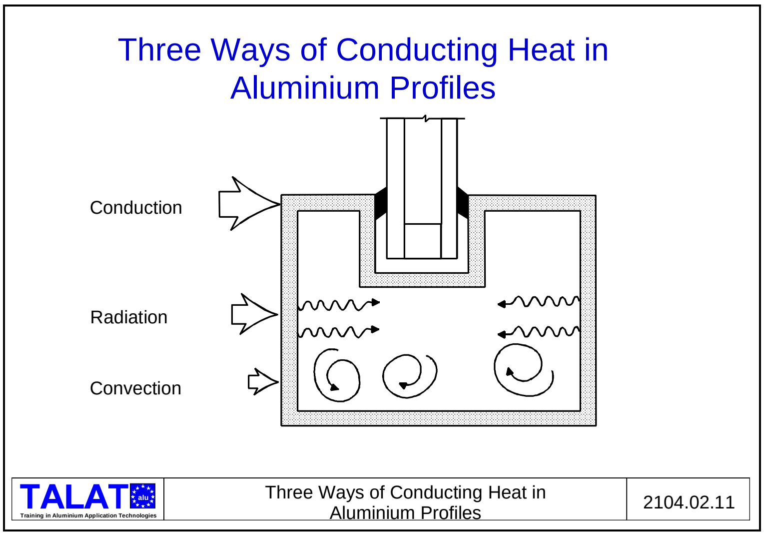


Mainly an extruded polyamide strip, reinforced with 25% glass fibre is introduced into a track in the profiles and clamped. This substance allows thermo-setting after surface treatment up to 200 °C approximately, which means that the profiles can be assembled before surface treatment. This reduces the risk of damage to the surfaces in the event of assembly taking place after treatment.

Another method is to cast the insulator against a casting frame between the surfaces, using a two component polyurethane based substance. The casting frame can be of a cheap plastic-based material or a thin-walled section of the aluminium profile which is later cut away. The disadvantage of this system is that the insulator melts at temperatures above 100 °C and all surface treatment must be done before assembly with the risk of damage as mentioned above. A certain shrinkage has been noticed recently over time, which has led to water leakage round the insulation retainers in the aluminium profiles. The future of this system is thus somewhat uncertain.

The third system consists of a hard plastic profile which is fed over flashes in the aluminium profiles and in this way holds them together. The method is relatively primitive and not especially widespread, but it is a cheap solution. The plastic profile will not tolerate temperatures above 100 °C.

Previously, hard polyurethane foam was used as an insulation between the surfaces. This had the great advantage that, in addition to having good rigidity and strength, it was also a good insulator, because it reduced thermal conductivity and also convection and radiation between the surfaces. The strip method only reduces thermal conductivity, and it is necessary to fill the cavity between the surfaces with an insulation material as an extra operation in order to achieve the same as the foam. The foam method was banned in some European countries in 1991 for environmental reasons as Freon gas was used during the foam production process. Tests with other types of gas demonstrated much poorer solidity in the foam and the method has more or less fallen into disuse (**Figure 2104.02.11**).



Work is being done in several countries with a view to finding new and better materials for insulation between aluminium profiles. The initial requirements are relatively strict. The substance must tolerate at least 200 °C for 15 minutes without melting or warping. Thermal conductivity must be lower than in polyamide with glass fibre, 0.60 W/m•K, and the strength must not be less. The substance must in addition be environmentally friendly when the profiles are recycled. Polyamide without glass fibre has a conductivity of 0.27 W/m•K **(Figure 2104.02.12)**.

Thermal Conductivity for Some Actual Materials

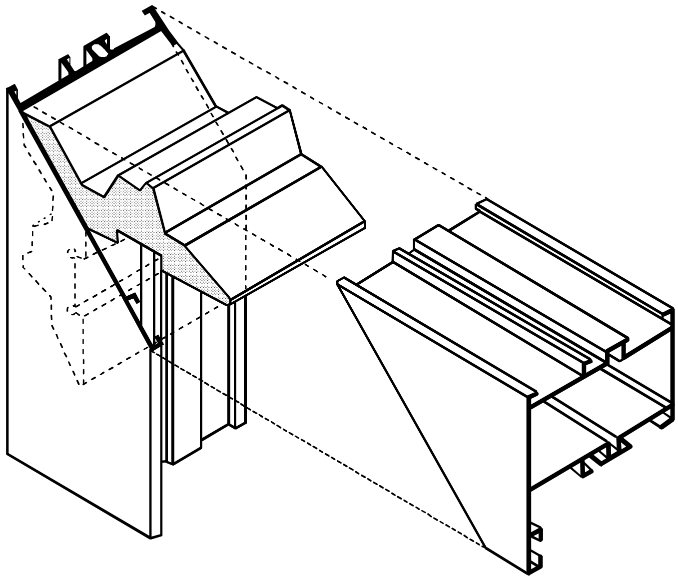
Aluminium	**220.00**	**W/m K**
Glass	**0.09**	
Polyamid PA 66 with 25% Glass Fibre	**0.60**	
Polyamid PA 66 without 25% Glass Fibre	**0.27**	
Foamed Plastic (PVC, PUR, etc.)	**0.02-0.10**	

TALAT Training in Aluminium Application Technologies | Thermal Conductivity for Some Actual Materials | 2104.02.12

Corner connections

Since an aluminium window has similar profiles on all sides these can be cut at an angle of 45° and mitred. As water-conducting drainage channels are built into the profiles, it is important that the corner joints should be made watertight. The joints must be flat and with no unevenness at the join. Normally special elbows are inserted in the ends of the profiles, and on assembly, part of the edge of the profile is pressed into a notch in the elbow which thus gives a good, firm connection at the corners. Special tools have been developed for this operation. The elbows can also be laid in a sealant in the profiles, which gives a good and invisible seal in the corner after assembly. Crossbars in the structure are abutted to the frame and are fixed by means of screws. Any water which has penetrated the horizontal crossbars is carried sideways out to vertical side profiles where the water runs down and out into the drainage channels in the bottom of the window itself (**Figure 2104.02.13**).

Corner Connection with Special Corner Elbow

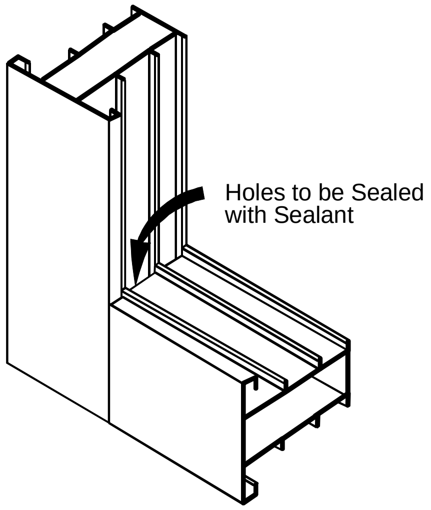


TALAT alu Training in Aluminium Application Technologies	Corner Connection with Special Corner Elbow	2104.02.13

For simpler structures in warmer climatic zones where uninsulated profiles are sufficient, the corner connections are often in the form of butt joints fixed with screws. One is then completely dependent on a sealer being laid in the corners after assembly to ensure watertight corners. This applies only to the two bottom corners of the window. This is a simple and cheap solution which can suffice in such climatic zones (**Figure 2104.02.14**).

.

Corner Connection with Butt Joint



TALAT Training in Aluminium Application Technologies | Corner Connection with Butt Joint | 2104.02.14

Surface Treatment

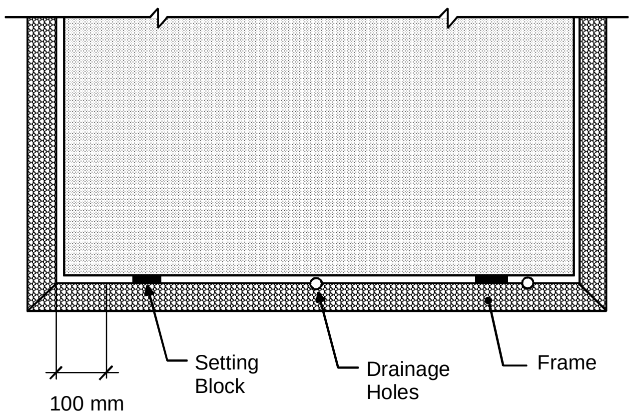
Under normal circumstances aluminium does not require anti-corrosion surface treatment since the metal itself forms a thin protective layer when in contact with air. If it is desired to improve this layer for any reason, the profiles need to undergo anodic treatment which is an electrolytic process.

For technical or aesthetic reasons coloured profiles are often required instead of a shiny, reflective surface. In this case, there are two possibilities: by means of anodising, which is also an electrolytic treatment, one can attain a surface coating with a very restricted range of colours. Nevertheless this allows a wear-resistant and relatively flat surface. If other colours are required, powder painting is the only possibility. With this method there is a wide range of shades of colour and the surface acquires an orange peel-like structure. As mentioned above, powder painting requires a hardening temperature of roughly 200°C, and the insulator chosen will determine in what order the insulation and surface treatment must be carried out.

Glass

A window is made up of aluminium profiles together with glass and fittings. Before the glass is fitted the profiles themselves may seem somewhat unstable and not at all rigid. Hence, correct and exact assembly of the glass is very important. The glass is assembled upon setting blocks, and support blocks must be adjusted very exactly to fit the cleft between glass and profile in order to convey the rigidity of the glass to the aluminium profiles. The setting blocks for the glass must not be placed so as to block off the drain holes in the structure **(Figure 2104.02.15)**.

Placing of Setting Blocks and Drainage Holes

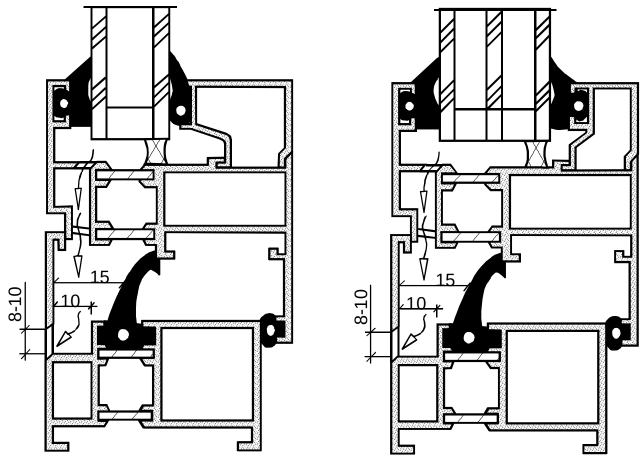


TALAT Training in Aluminium Application Technologies | Placing of Setting Blocks and Drainage Holes | 2104.02.15

Slight variations in the glass thickness may be taken up by means of packing on both sides of the glass, whilst the use of different glass dimensions in the same basic structure must be solved by means of different sized beads **(Figure 2104.02.16)**.

In the event of breakage it must also be possible to change the glass in a simple manner.

Same Construction for Different Glass Dimensions



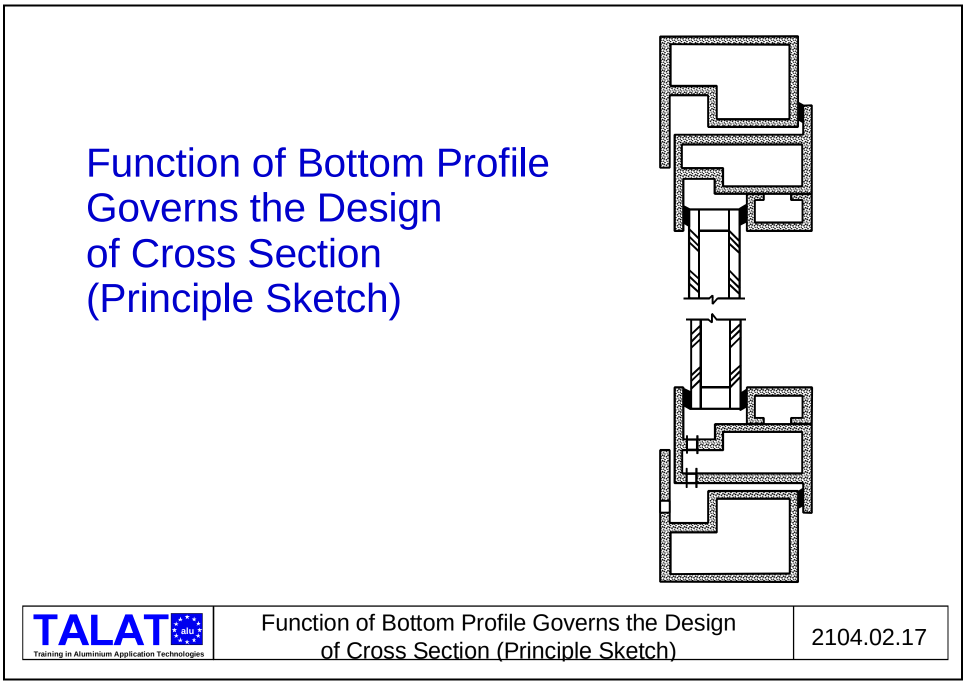
TALAT Training in Aluminium Application Technologies | Same Construction for Different Glass Dimensions | 2104.02.16

Fittings, accessories

Unless expressly prescribed, the profiles should suit the existing hinges and closing mechanism. This allows straightforward assembly on the part of the manufacturers and at the same time exact positioning of the fittings in the structure.

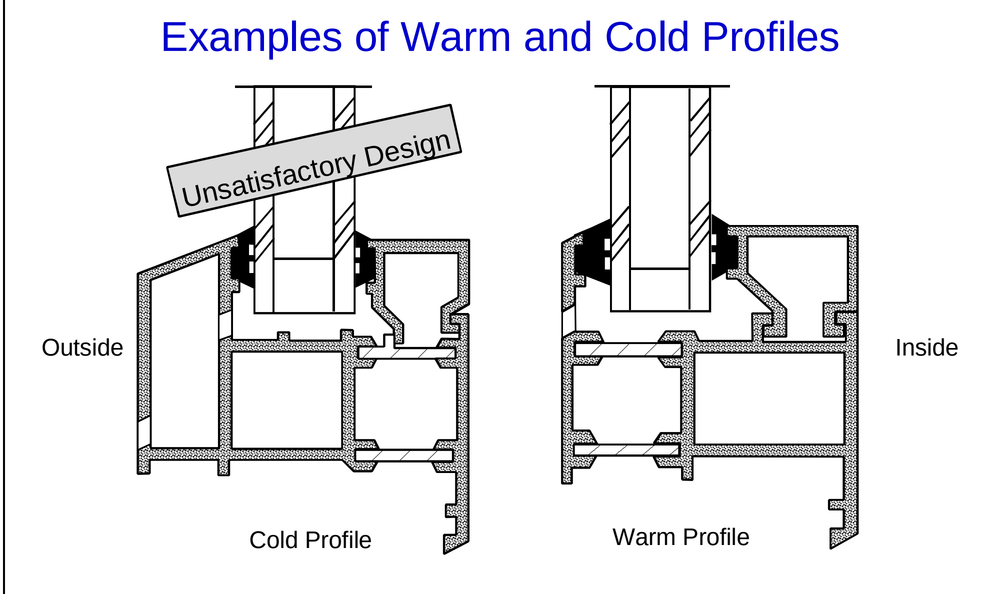
Some advice on window design

- Determine which type of window is to be produced. There are several ways of hinging the same profile system. It should just be born in mind that inward opening and outward opening frames cannot be combined in one and the same profile system.
- Establish what profile heights and widths are acceptable to the market.
- Commence work by designing the lower horizontals of the window. These are most exposed to the penetration of water, and require particular minimum-size drainage channels and also correct and appropriate placing of seals (**Figure 2104.02.17**).



- Determine the dimensions of the insulation material and its positioning dependent on the degree of insulation to be attained. Consider this in relation to the acceptable profile depth.
- Ensure that tracks in the profiles are suited to the existing hinges and the closing and locking mechanism.

- Make sure that the rebates are deep enough to provide sufficient protection of the edges along a sealed pane, and allow sufficient extension of the glass towards the profiles. (Glass manufacturers recommend 18-20 mm)
- Make sure that fittings and screws do not form a cold bridge in insulated structures.
- In an insulated structure, design the outer profile as small as possible in depth and the inner one as deep as the total structure permits **(Figure 2104.02.18)**.



TALAT Training in Aluminium Application Technologies | Examples of Warm and Cold Profiles | 2104.02.18

List of Figures