

**Introduction**

**WINDOWS a COMPEHENSIVE GUIDE**( edited by)

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“**Window** - An opening in the wall or roof of a building, fitted with glass in a frame to admit light or air and allow people to see out” ‒ this true but simple definition of a window given by the Oxford Dictionary of Contemporary English is a matter of common knowledge. Everyone can see what a window is like, and everyone knows what a window is for.

But is it really that simple? It is not! Modern windows, and more precisely uPVC windows, are highly sophisticated systems of a multitude of components that perform very different functions and that have to meet specific requirements.

The basic requirements that every window must meet are defined in the applicable regulations pertaining to construction technology. After a window is installed in the wall of a building, it must perform the following functions:

separate the interior of the building from the exterior (so as to ensure suitable indoor climate and prevent the elements from affecting it);

ensure proper thermal insulation;

ensure proper acoustic insulation;

ensure proper air- and water-tightness of the opening in the wall in which the window is installed;

let an appropriate quantity of daylight inside the building;

let in air that is needed for proper operation of the ventilation system inside the building;

protect the interior of the building against unauthorized access from the outside;

transfer the loads caused by the forces acting on the window to the structure of the building.

All or only some of the aforementioned functions are performed by windows thanks to their properties. Within Europe,the required properties of windows made of PVC are defined in the EN 14351-1+ A1:20101 standard. The extent, to which a given window has certain properties and, simultaneously, meets the requirements of the building owner, determines the application and use of the window. In this document we will make many references to the aforementioned

standard and the term “properties of windows”

Please note that this and many other standards quoted in this book are European standards that might not apply in your country. They can still serve as a reference, but you should nonetheless check the applicable local building regulations.

The ability to select and determine the properties of a window is necessary in practice to ensure long, reliable, and,most importantly, safe use of the window with the level of its functionality changing as little as possible.

For some readers this may sound quite mysterious, but we will explain it soon. For now, we will demonstrate why each window must have certain properties in order to perform the functions we have itemized. This requirement is due to the daily “fight” between our window on one side and the elements and gravity on the other. Look at the figure below and see the forces that act on each window installed in a building wall each day, hour after hour.

**FORCES ACTING OF A WINDOWS**

* Movements of the Building
* Outdoor temperature,
* rain, wind, sunlight,
* noise
* Indoor Temperature
* air humidity
* Weight of the Window
* Movement of Window element



In order to maintain its functionality, a window must compensate each of the forces with one of its properties. If the“value” of the property is equal to or greater than the force acting on the window, we can rest assured that the window will be safe; however, if the forces of nature are greater, then at best we will need to file a complaint and at worst wewill have to replace the window with a better one. The new ones will need to have the required properties.

When talking about the functions a window has to perform, we have to keep in mind that it is not only the window andits quality that determines whether the installed window can meet the requirements, but also the quality of the installation in the wall. Professional installation carried out by experts comprehends proper fastening to the wall structure and sufficient and correct insulation and sealing of the joints. In chapter 6 we will describe how to correctly install windows according to the state of the art.

Besides these pragmatic functions, the window has also an architectural design aspect. A wide range of different shapes and colours offers an almost unlimited freedom of design to planners, architects and building owners. Further more, uPVC window profiles can be laminated with decorative foils that perfectly imitate wooden surfaces or they can be covered with aluminium shells, which again can be coloured in the so-called powder-coating process. Manifold shapes and overall pictures of windows can be created, from “normal” windows over round windows, arched and segment bow windows, with or without window bars and in a modern or antique design. You will find detailed information on the design possibilities a uPVC window offers.

The reader will find numerous references to standards, building codes, regulations and empirical facts. Even though this guide tries to give a general overview with universally valid information, the authors somehow had to refer to standards and regulations. In this regard, they mainly focussed on the European norms that are considered exemplary throughout the world.

**What actually is PVC?**

Before we start to dig into the history of PVC windows, let us first define what this material actually is.

Polyvinyl chloride, PVC for short, is a plastic. Plastics are synthetic materials consisting of organic molecule compounds which have been polymerized by chemical processes, i.e. by splitting up organic natural compounds into their low-molecular components and linking the vinyl chloride monomers to form chains of PVC. As a thermoplastic synthetic material, PVC is heat mouldable. The window profile material PVC is one of the oldest plastics, and as such one of the most thoroughly researched and developed ones. It can be found in the most diverse fields of application, from the automotive industry over construction elements, everyday goods, up to medical equipment. The cured PVC

is 100 % harmless to health, and for this reason uPVC windows can be installed even in sensitive environments such as hospitals, nurseries and schools. Due to its diverse processing and application possibilities, PVC beats all other synthetic materials and prevails on the plastics market since the 1950’s. Moreover, thanks to its technological advantages,

PVC replaced many other non-plastic materials, such as metals, in various fields of the industry (e.g. underbody skid plates, window frames, roller shutters, cable sheath).

In the first half of the 19th century, the development of the first plastics started. After some extensive basic research

from around 1910 on, first production started in Germany, the USA and Great Britain in the 1930’s. After the Second World War, i.e. since the 1950’s, PVC is mass-produced for pipes, profiles, floor coverings and many more.

**Types of plastics**

In general, plastics can be subdivided into the three main groups thermoplastics, thermosetting polymers and elastomers.

These groups differ in their physical behaviour, particularly regarding their mouldability under heat:

**Thermoplastics** (also called plastomers) have very long, threadlike molecular chains. Upon heating, they become soft and mouldable. Upon cooling, intermolecular forces increase again and the thermoplastic becomes rigid. Thermoplasticsare remouldable, which is the most significant difference to other plastics. The window profile material PVC is a thermoplastic.

**Thermosetting polymers** in turn are generally not heat-formable. Once they are cured they cannot become soft and pliable or mouldable again, even upon heat. Polyurethane insulating foams are one example for thermosetting polymers.

**Elastomers** are molecules of long polymer chains. They have a very high viscoelasticity; at normal temperatures elastomers are elastic, at very low temperatures they become more rigid. Gaskets used in windows consist of elastomer materials.Excessive heat can split up the macromolecules and by this means destroy the plastic material. This is true even forthe heat-formable thermoplastics. This is important to know when it comes to welding the PVC window profiles, butalso when processing the insulating foams and gaskets.

Pure PVC is pretty rigid at a temperature of around 100°C. Only between 100°C and 180°C it is viscoelastic. In order to achieve elasticity also at room temperatures, certain plasticisers are added to the compound. These additives keepthe PVC soft even at very low temperatures, e.g. in PVC foils that are still flexible at a temperature of -20°C. The possibility to add plasticisers is a special characteristic of PVC.

**Performance characteristics of uPVC**

uPVC, i.e. unplasticised, rigid PVC (the type of which PVC window profiles are made of), presents the following beneficial

performance characteristics:

high mechanical stability, stiffness and hardness;

notch-insensitive material with normal to high impact resistance;

high creep rupture strength;

high abrasion resistance;

high fire resistance and self-extinguishing outside the flame;

high resistance to chemicals and weathering;

good solubility in certain solvents, for this reason suitable for adhesion;

weldable;

physiologically and environmentally harmless;

various colours from opaque to transparent can be fabricated;

high dimensional stability due to low shrinkage;

high UV resistance (special PVC recipes for tropical and sunny regions).

**Advantages of uPVC windows**

Windows with frames made of uPVC dominate the window market. Why? In general, there are obvious ecological and economical advantages on the one hand, and on the other hand, there are those advantages related to process ability,design, easy care and safety. Here are some very good reasons and arguments for windows made of uPVC in the three categories ecological, economical and material-/safety-related advantages, which, of course, are to be understood as rough categories, as most advantages intertwine. For example, energy efficiency is an ecological advantage that at the

same time has clear economical advantages.

 **Energy efficiency**

uPVC windows are energy efficient. They have a very low heat transfer coefficient, that is they have very good insulating properties. In the previous chapter, we briefly introduced the heat transfer coefficient, known as U-value. The heat transfer coefficient indicates how much thermal energy (heat) is transferred through a building element such as the wall, the roof, or in our case the windows and doors. In the case of windows and doors, it is divided into the Uvalue for the frame only (Uf), the U-value for the glazing only (Ug), and finally the U-value for the entire window element,comprising frame structure and glazing (Uw). The unit is W/m²K (Watt per square metre by Kelvin). The lower the value the less thermal energy is lost through an element and the better are the insulating properties of the same.

**Harmless to health**

As mentioned above, uPVC windows do not emit any gases and can be considered as absolutely harmless to human health. Due to this fact and thanks to the easy-to-clean and hygienic, non-porous surfaces of uPVC window frames, they are suitable even for installation in clinical environments. In December 2010, the German test institute ift Rosenheim

in cooperation with Rosenheim University of Applied Sciences completed a research project on emissions from construction elements10 that investigated the emission behaviour of windows made from different materials. The result:

uPVC windows have no or only minimal VOC (volatile organic compound) emissions and meet all applicable

regulations on VOC-emissions.

**No deforestation**

**Material-, design- and safety related advantages**

 uPVC windows offer good sound insulation.

uPVC windows are fire-resistant, do not have a fire-accelerant effect and are self-extinguishing outside the

flame.

uPVC windows are resistant to termites, will never rust, rotten or corrode.

uPVC windows can be cleaned easily with normal washing-up liquid.

uPVC windows provide protection against burglary.

uPVC windows can be produced with coextruded gaskets, so the sealing will fit properly.

uPVC window profiles can be lacquered, laminated with décor foils, or covered with aluminium shells.

uPVC window profiles can be bent. By this means, arched and even round uPVC windows are possible.

 uPVC windows can be installed both in new buildings and in renovation projects.

**Performance characteristics of uPVC Windows**

Shared characteristics

We concluded that practically every PVC window is made from the same basic structural components.

However, the similarity of the components used by different manufacturers does not mean that all the windows are exactly the same. What determines the performance, the intended use, and the potential application of windows in specific buildings is the performance parameters. This is why this chapter focuses on performance characteristics of windows, namely a set of strictly defined characteristics determined in laboratory tests and assigned tested window structures.

The EN 14351-1+A1:2010 standard identifies and defines as many as 23 different performance characteristics of windows and defines different classes or values for each of them. The full list of performance characteristics, as defined in the aforementioned standard, is given below:

1) Resistance to wind loads - test pressure

2) Resistance to wind loads - window frame bend

3) Resistance to snow load and permanent load

4) Reaction to fire

5) Water tightness - uncovered windows

6) Water tightness - covered windows

7) Hazardous substances

8) Impact resistance

9) Load-bearing ability of protective devices

10) Acoustic properties

11) Thermal transmittance

12) Properties related to radiation - solar radiation factor “g”

13) Properties related to radiation - light transmittance “Lt”

14) Air permeability

15) Operating forces

16) Mechanical strength

17) Ventilation

18) Bullet resistance

19) Explosion resistance - shock tube

20) Explosion resistance - range test

21) Resistance to repeated opening and closing

22) Behaviour in different climates

23) Burglary