

Reduction of Light Transmission by Glazing with Atmospheric Pollutants

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Abstract. Daylight has been used for centuries as the main source of light in interiors and has always been an implicit part of architecture ever since buildings exist. Daylight is an irreplaceable environmental factor and is a prerequisite for a healthy stay in buildings. Ensuring daylight access to the interior is a challenge when designing buildings. The aim is to provide enough daylight for the visual work that indoor building users do. The deposition of air pollutants on the glazing can significantly affect the transmission of daylight into buildings located in urban areas. This study shows the impact of air pollution on glazing permeability in three cities in the Czech Republic. The throughput was measured on a total of 9 windows for half a year. Air purity, exposure to rain, the slope of glazing and use of rooms are factors influencing the final permeability of the glazing. Where glazing is exposed to rain, dirt on the outside of the windows tends to accumulate. The final reduction in throughput is usually 4-8%, with some exceptions.

1. Introduction

Daylight in cities is reduced by air pollutants and debris deposited on the surface of buildings. Air pollution causes attenuation of incoming visible radiation. The deposited dirt reduces the reflectance and permeability of building materials.

Glass contamination means visual difficulties caused by the darkening of exposed surfaces by deposition of atmospheric particles [1]. Pollutants are primary particles - fine solid or liquid substances such as smoke particles or dust consisting of alumina, calcium fluoride, cement, coal, grains, limestone, metals, ores, rocks and wood [2]. Pollution has been shown to occur on surfaces exposed to direct rain, indicating that rain washing is not fully effective [3].

Pollution has mostly been studied on glass exposed environments in urban environments. The results of these investigations show that surface deposits consist of mixtures of insoluble (solid residues, fragments rich in metals and black carbon) and soluble (salts rich in S, C and N and organic species of organic matter particles) particles [4-6] and their nature is relatively representative of the abundance of airborne particles present in exposure areas [6].

Between 1999 and 2003, several field surveys were conducted in the UK and Singapore [7-9]. The decrease in daylight transmission caused by the deposition of pollutants in urban buildings was measured here. In the UK, a 4-8% reduction in permeability for commercial buildings in a clean environment was



measured, while further research [8] reported diffuse permeability values for vertical windows typically up to 10%. A survey conducted in Singapore that has a high density and tropical humid climate indicates a reduction in overall throughput ranging from 9% to 36% for vertical and horizontal windows [9].

This work deals with air pollution and glazing in the Czech Republic, specifically in three cities and different types of buildings. Glass permeability measurements were performed once a week on 9 windows. These data formed the basis of the project.

2. Air pollution and glass permeability measurement

Airborne dust is small particles of various substances that are so light that it takes a very long time to settle on the surface, and due to this property, the term "airborne dust" known as PM has become known. We distinguish categories PM₁₀, PM_{2.5} and PM_{1.0}, by particle size. For example, PM₁₀ are particles up to 10 microns = 0.001 mm. The smaller the particle diameter, the longer it stays in the air. PM₁₀-size particles "fly" in the air for several hours, PM_{1.0} and several weeks until they are flushed out by rain.

The airborne dust consists mostly of sulphates, ammonium salts, carbon, some metals, nitrates, or even volatile organic compounds or polyaromatic hydrocarbons [10].

Outside air pollution is low for dust fall below 50 Mg·km⁻² per year and high for fall above 200 Mg·km⁻² per year. Indoor air pollution is considered medium in clean workshops, warehouses, etc., large with significant sources of dust in the interior - eg dusty workshops [11].

In the Czech Republic, the 24-hour limit of 50 micrograms per m³ applies to PM₁₀ airborne dust, which limit can be exceeded 35 times a year. Another applicable limit sets the highest average concentration for the whole year at 40 micrograms. However, according to the latest studies, lower concentrations of airborne dust may also have harmful health effects.

Regardless, the limit value for airborne dust is exceeded in one third of the territory of the Czech Republic. However, in this third of the territory, two thirds of the population are exposed to dust and face increased health risks. In the Czech Republic and Poland, the situation is the worst of the European Union. In comparison with air quality in about 30 large European cities in terms of airborne dust pollution, Prague was the worst city ever. The European Union wants to tighten the limit so that the limit of 50 micrograms per cubic meter should not be exceeded more than seven times a year. This has made the existing criterion tolerant of exceeding the set limit thirty-five times more stringent.

Glass permeability measurements were carried out for six months at several locations in the Czech Republic. The first locality was in the center of the regional town of České Budějovice, the second locality was on the outskirts of Hluboká nad Vltavou and the third locality was in the center of the regional capital Brno. The measurements were performed on several different windows with different orientation. The windows were washed before the first measurement and then the glass permeability was measured once a week.

A sample of 9 windows was selected in the study, representing different atmospheric environments in cities and different types of building designs. The buildings were selected in the city center and on the outskirts. The buildings had transparent single or double glazing, different types of heating, vertical and sloping windows, rooms with different functions (from bedrooms to school areas) and windows at different heights above ground level. The core of the sample were the following buildings: a residential unit in the center of České Budějovice (fourth floor), a family house on the outskirts of Hluboká nad Vltavou (second floor) and a university building in the center of Brno (third floor).

For each window, the permeability was first measured on the cleaned glazing from the interior and exterior, and then weekly on progressively soiling windows. Measurements were made using the Pocket

Detective 2.1 Transmission and Reflectance Meter and the Window Energy Profiler - an Energy Transmission Meter for Testing Operable Windows In-Frame.

3. Results

Figure 1 shows the main result of a field study. It shows the loss of throughput in percent in all measured windows. Said loss of permeability is attenuation due to impurities. It does not include the permeability values of actual glazing materials.

Most values are below 10% and only one value (roof window in the university building) exceeds this pollution, all values are less than 15%.

The findings from data analysis by location and use of the room were as follows:

- The reduction in light caused by impurities inside the glazing was usually at least as great as external contamination. In general, the use of the room was an important factor.
- The amount of external debris on the windows was related to the air quality in the immediate surroundings, especially the concentration of particles in the atmosphere.
- External contaminants were significantly affected by precipitation and slope glazing. Windows near the ground were a little dirtier than windows higher on buildings, horizontal windows were dirtier than vertical windows, the glazing exposed to heavy rain was cleaner.

Figure 1. Reduced glazing permeability due to dirt.

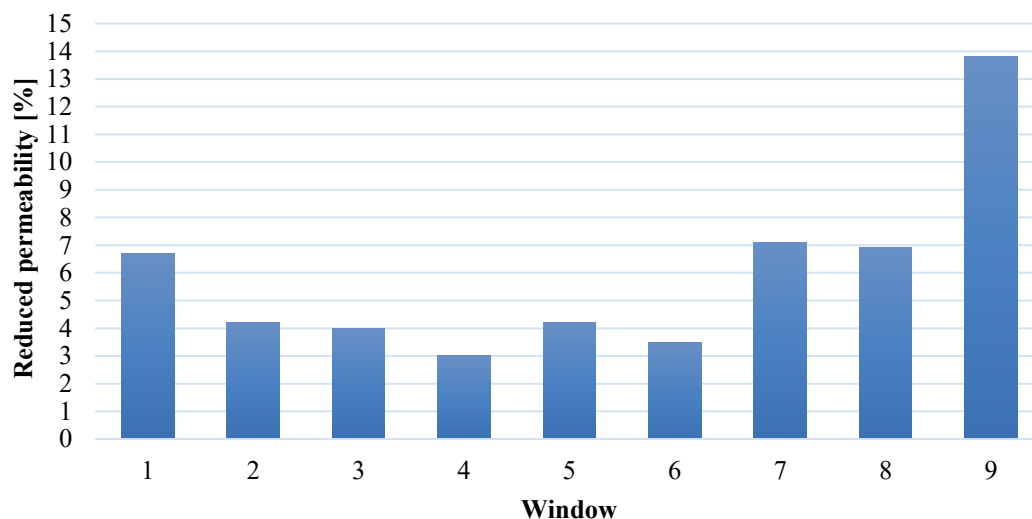


Table 1 and Table 2 are guidelines for the typical loss of daylight transmission due to the build-up of dirt on the glazing. Table 1 shows the percentage loss in relation to room function and building location. Table 2 shows the corrections for the different exposure levels and the type of glazing.

It should be noted that the tables give typical figures based on the measured mean values. The measurement took place in three cities of the Czech Republic. In the future, it is necessary to measure more samples in order to create a table for all room functions and window exposure throughout the Czech Republic.

Table 1. Typical percent reduction in glazing through dirt deposition.

Room function	Location	
	Suburban	Urban
<i>Residential</i>		
Private rooms and common areas, few residents, good maintenance, no smoking	4%	6%
<i>Commercial, educational</i>		
Rooms used by groups of people, spaces with office equipment	Not measured	7%

Table 2. Corrections to be applied to the values in Table 1 for different exposure conditions.

Exposure	Slope of glazing	
	Vertical	Inclined
Exposed to heavy rain	x 0,5	x 1,5
Normal exposure location	x 1	x 2

The values in the tables can be used as follows:

- Vertical window to the classroom in the city district, normal exposure. From Table 1 we take 7%; multiply x 1 from Table 2, bringing a final reduction of 7%.

4. Conclusion

Daylight is one of the most important environmental factors. The indoor environment of buildings is one of the basic parameters that affect human health and is second only to the lifestyle of the population. Daylight cannot be replaced by artificial sources and together with direct sunlight it is an essential part of our environment as well as air, water, earth's gravity and so on.

Measurement of window transmittance during half a year of non-washing has shown that the pollution of the glazing significantly affects the resulting amount of luminous flux passing into the interior. The greatest difference in permeability after washing and after half a year of non-washing was 7.1% for vertical windows and 13.8% for horizontal windows. The location, orientation, location and material of the glazing have an influence on the resulting amount of pollution for a particular window.

Daylight entering the interior through windows is reduced due to air pollution. The average values of reduction permeability glazing can be found in the tables above. Imposition of impurities is influenced by the function of the room, the concentration of particles in the atmosphere, precipitation and the shape of the building.

Cleaning the exterior windows affects the daylight that permeates through the windows, but has less effect than washing the windows from the interior, because the windows on the exterior side are usually naturally washed by rain. Frequent cleaning of the interior can increase daylight if the interior atmosphere is very humid or contaminated by smoke or dust. Glazing that is shielded from the exterior by overhangs can accumulate more dirt. Here, the relatively low throughput must be compensated for by a larger glass area or by ensuring frequent cleaning.

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