POSTULATE FOR AIRTIGHTNESS LIMITS IN LARGE BUILDINGS

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ABSTRACT

DIN 4108-7 requires a limit of $q_{50} \leq 3.0$ m³/m²h for the air permeability of large buildings. Even stricter limits with respect to q_{50} can be found at DGNB [German Sustainable Building Council] and in the Swiss MINERGIE Standard.
It is the objective of this presentation to develop awareness of this topic in the audience and to give recommendations as to which limits can be applied to new building projects.
Theoretical considerations and experience from measurements lead to the conclusion that a volume-based limit of n_{50} is not a suitable target value for large buildings. Because of the changing surface-area-to-volume ratios (SA:V-ratio) in large buildings, it makes sense to require an envelope-based limit, especially since there are requirements for limiting air permeability for building component joints and service apertures. Existing limits and results from airtightness measurements are presented. The presentation will also outline the main points of the approach to achieving airtightness as planned.

KEY WORDS

Air permeability q_{50}, limits (table), roll-up doors, loading bridges, smoke extraction for elevators

INTRODUCTION

Airtightness tests of large buildings such as office buildings, schools, homes for the elderly, warehouses, and production halls are fortunately becoming increasingly common in Germany. They are frequently performed in order to meet the requirements or exploit the benefits of building airtightness as defined in the German Energy Savings Regulation or conducted because of increased public awareness as to preventing waste of energy. Another reason is the ever higher number of quality certificates required.

Photos:
Left: www.hammersen.de
Right: www.sanidetectif.be

Figure 1: Two buildings with an internal building volume of 200,000 m^3 each. The building on the left with a V_{50} = 2,600 m^3/h is very airtight. The building on the right has a V_{50} = 86,500 m^3/h.

LIMITS AND MEASURED VALUES

Air change rate n_{50} at 50 Pascal

The German Energy Savings Regulation limits the air change rate n_{50} of a building to the following values when conducting an airtightness test according to European Standard EN 13829:

$n_{50} \leq 3.0\ h^{-1}$ for buildings without a ventilation system and
$n_{50} \leq 1.5\ h^{-1}$ for buildings with a ventilation system

According to the German Energy Savings Regulation 2007, the energy balance for non-residential buildings is calculated according to the series of German Industrial Standards DIN V 18599. Based on the project experience of Mr. Moritz Wagner, Dipl.-Ing., of Büro IFB Sorge (Nuremberg), the following can be stated with the DIN V 18599 assessment:

- Considering an airtightness test usually has a positive effect on the annual primary energy requirement.
- For common types of buildings, the reduction comes to 10-15%.

The German Industrial Standard DIN V 18599 allows for applying the measured n_{50}-value as a rated value. The standard rated value according to DIN V 18599 for buildings without ventilation systems is $n_{50} \leq 2.0\ h^{-1}$ and for buildings with ventilation systems is $n_{50} \leq 1.0\ h^{-1}$. Figure 2 shows that the real measured values often amount to $n_{50} \leq 0.5\ h^{-1}$. By using the real measured n_{50}-values, improvements in the energy balance beyond the standard rated values can be expected.

It is important to determine this value according to Method A in German Industrial and European Standard DIN EN 13829.

The experience from testing large buildings has shown that the limits of the German Energy Savings Regulation and German Industrial Standard DIN V 18599 are usually met and to some extent the measured values remain far below them. The following diagram shows a compilation of the air change rates at 50 Pascal (depressurization tests) of 82 buildings measured by a series of testing teams. The smallest building has an internal volume of approximately 1,300 m^3, the largest one of approx. 520,000 m^3.

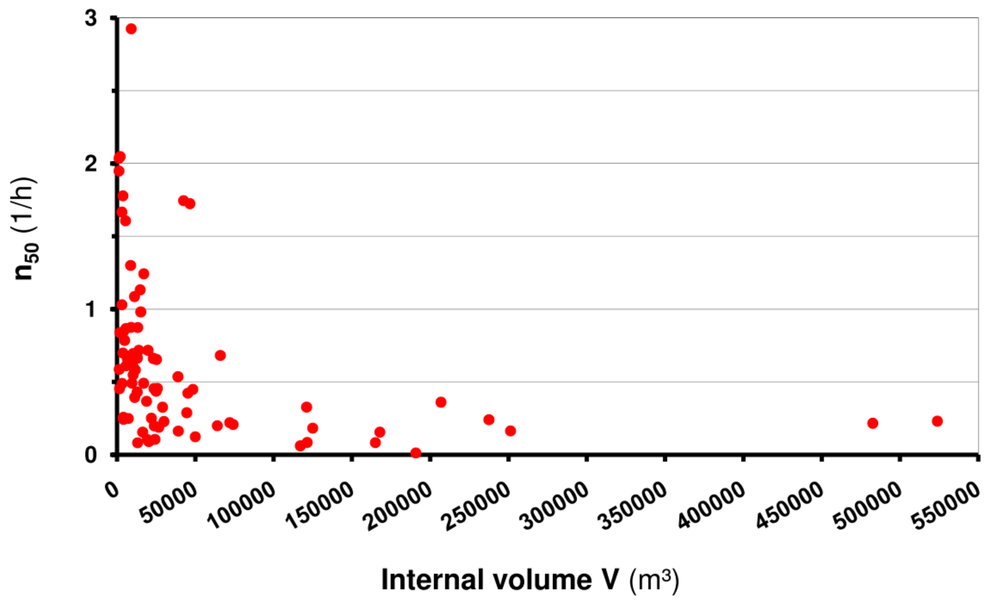

Figure 2: Air change rates n_{50} (82 depressurization tests) of large buildings

The air change rates of all buildings are below 3.0 h^{-1}. Almost 90% of the air change rates are even lower than 1.5 h^{-1}.

What is the reason for these seemingly excellent results for the air change rates at 50 Pascal? Is the quality of the building envelope of large buildings so much better than that of single-family homes? Or are there other reasons?
The air change rate n_{50} is a volume-based indicator. It is calculated by dividing V_{50}, the leakage flow determined at 50 Pa, by the internal building volume V:

$$n_{50} = V_{50} / V$$

This results in large buildings achieving better (lower) air change rates than single-family homes because they have a smaller SA:V-ratio (surface-area-to-volume ratio), which means that a “large” volume is enclosed by a relatively small building enveloping area containing the leakages.

Examples for SA:V-ratios:

Type of building	**SA:V-ratio(1/m)**
high-rise building	from 0.2
apartment building/multiple family home (MFH) (3 to 4 floors)	approx. 0.3 to approx. 0.6
center row house (2 to 3 floors)	approx. 0.5 to approx. 0.7
single-family home (SFH)	from 0.8

In this context, the air change rate n_{50} does not yet provide any information on the quality of the building envelope. An evaluation can only be conducted when the air change rates of the same quality of the airtight layer are related to the SA:V-ratios.

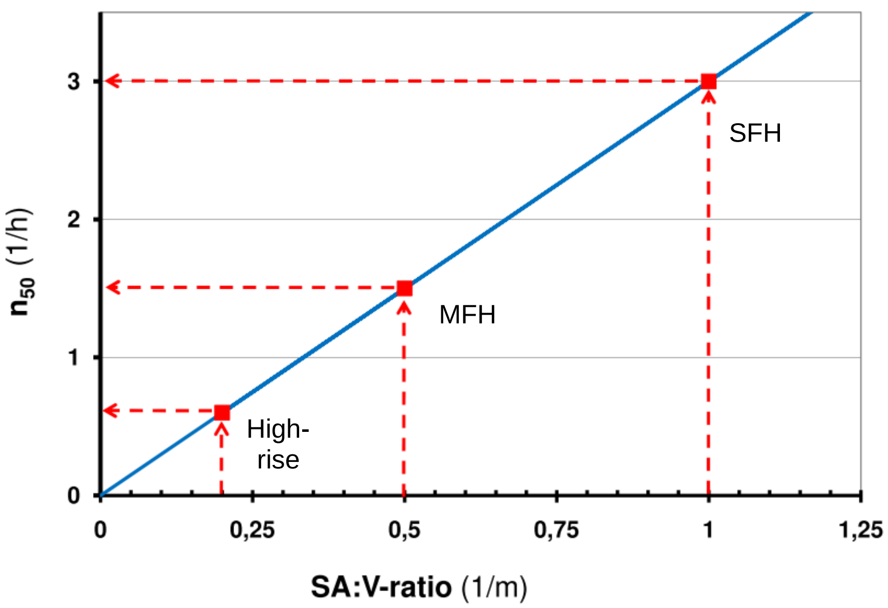

Figure 3: Air change rates of the same quality of the airtight layer related to the SA:V-ratio

The diagram shows the example of three buildings: a single-family home (SFH) with a SA:V-ratio of approx. 1 m^{-1}, an apartment building/multiple-family home (MFH) with a SA:V-ratio of approx. 0.5 m^{-1}, and a high-rise building with an SA:V-ratio of 0.2 m^{-1}. The single-family home at 50 Pascal is supposed to have a maximum air change rate of n_{50} = 3.0 h^{-1}. Assuming that the multiple-family home and the high-rise building feature just as many leakages per square meter of enveloping area, the airtightness test of the multiple-family home would determine an air change rate of n_{50} of 1.5 h^{-1} at 50 Pascal and that of the high-rise building a rate of 0.6 h^{-1}.

CONCLUSION

The air change rate of large buildings should always be evaluated in relation to the SA:V-ratio of the building.

Air permeability q_{50} at 50 Pascal

To better compare the quality of the building envelope of different buildings, an additional indicator can be used: the air permeability q_{50}. German Industrial Standard DIN 4108-7 in its version of January 2001 also requires limiting the air permeability for buildings with an internal volume of > 1.500 m³ to $q_{50} \leq 3.0$ $m^3/(h \cdot m^2)$.

The air permeability q_{50} is calculated by dividing the leakage flow V_{50} at 50 Pascal by the respective building enveloping area A_E:

$$q_{50} = V_{50} / A_E$$

It indicates how many cubic meters of air per hour at a building pressure differential of 50 Pascal flow over one square meter of building enveloping area.

The following diagram shows the air permeability q_{50} of 42 depressurization tests.

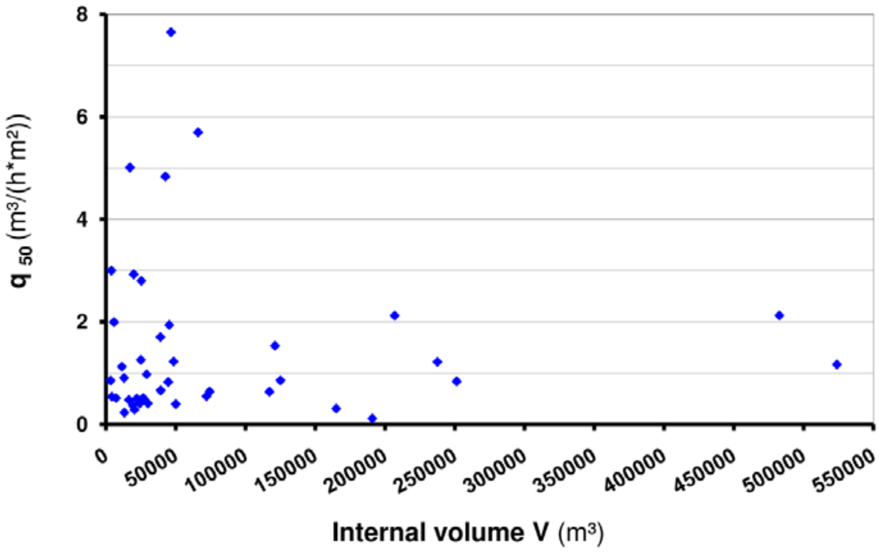

Figure 4: Air permeability q_{50} (42 depressurization tests) of large buildings

90% of the buildings meet a $q_{50} \leq 3.0$ m³/(h∗m²). 70% remain below a $q_{50} = 1.5$ m³/(h∗m²).

At an international level, limits for buildings larger than 1,500 m^3 have already been formulated:

• Minimum standard 4108-7	$q_{50} \leq 3.0$	$m^3/(h \cdot m^2)$	
• Minimum standard DGNB (German Sustainable Building Council)	$q_{50} \leq 2.5$	$m^3/(h \cdot m^2)$	
• Improved standard DGNB (German Sustainable Building Council)	$q_{50} \leq 2.0$	$m^3/(h \cdot m^2)$	rule of technology
• Swiss MINERGIE Standard	$q_{50} \leq 1.25$	$m^3/(h \cdot m^2)$	soon rule of technology
• Optimum standard	$q_{50} \leq 0.6$	$m^3/(h \cdot m^2)$	state of the art

Rule of technology means that these values are already met today by applying the generally used techniques and working methods. Since awareness in practice has been increasing, the authors estimate that the rule of technology will very soon shift towards a $q_{50} \leq 1.25$ $m^3/(h \cdot m^2)$.

State of the art means that it is possible to achieve these values by applying special diligence. This usually implies quality assurance during the construction phase. The authority for public buildings in Luxemburg already applies a limit of $q_{50} \leq 0.6$ $m^3/(h \cdot m^2)$ for new school or office buildings. For halls, the q_{50} is adjusted depending on the quality of the roll-up doors.

SUGGESTIONS FOR QUALITY IMPROVEMENTS

To purposefully achieve good quality in the airtight building envelope, an airtightness concept for the building should be developed as early as the planning phase, as is the case for single-family homes. The airtight layer as well as the thermal building envelope have to completely enclose the entire heatable volume. Selecting sufficiently airtight materials, planning details diligently and avoiding unnecessary penetrations are requirements for successful implementation later.

Based on the testing experience to date, improvement is needed for, for example, post-and-rail façade structures, smoke extraction in elevators, roll-up doors and movable loading bridges.

Post-and-rail façade structures

Figure 5 gives an example of early airtightness testing of a post-and-rail façade structure.

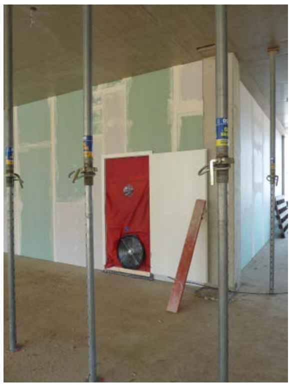

Figure 5: A sample façade with connected casing allowed the airtightness of the façade component and the connecting joint to be tested before construction. In this case, improvements and a second airtightness test were necessary.

Smoke extraction in elevators

Smoke extraction in elevators is intended for cases of fire. It is mostly an aperture at the elevator head. In case of fire, these apertures serve as smoke extractors from the shaft. Elevator doors in many cases are only authorized if smoke extraction apertures exist. If these apertures remain open all year, they cause ventilation heat loss or, in air-conditioned buildings, ventilation cold losses in summer. Flap valves that will only open as needed are now available on the market. In some cases, the smoke extraction apertures also serve to cool the elevator drive motor. Should this be the case, the function of the smoke extractor shutter can be combined with switch-on/switch-off temperature for cooling the motor.

Installation shafts frequently also feature smoke extraction, and thus also have to be equipped with flap valves.

Roll-up doors

Roll-up doors are used in many larger projects, e.g., warehouses. Table 1 shows the airtightness of roll-up doors: “Airtightness classes 0 to 5 for roll-up doors according to German Industrial and European Standard Din EN 12426.” The indicated values correspond to the q_{50}-value in German Industrial Standard DIN 4108-7. A roll-up door of the airtightness class 4 with an air permeability of 3 $m^3/(h \cdot m^2)$ corresponds to the limit stipulated in DIN 4108-7.

Class	Air permeability(AP) at a pressure of 50 Pa $m^3/(h \cdot m^2)$	Value defined
0		No value defined
1	24	
2	12	
3	6	
4	3	
5	1.5	

Table 1: Airtightness classes 0 to 5 for roll-up doors according to [DIN EN 12426]

Movable loading bridges

Different loading-bridge systems are in use for loading and unloading trucks.

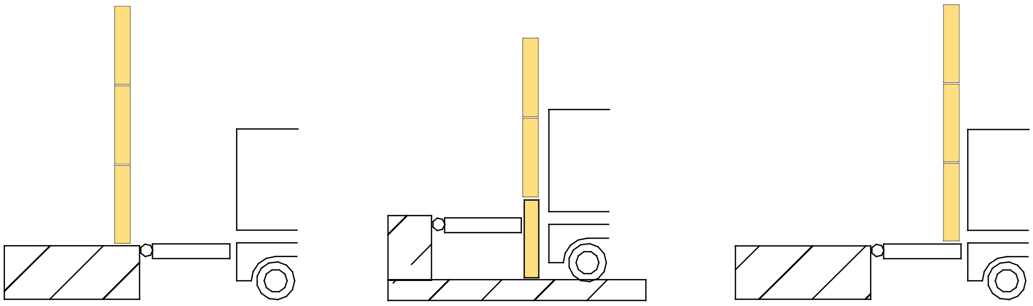

Figure 6: The loading bridge on the right has an effect on the airtightness since it forms part of the building envelope.

For loading bridges that form part of the external building envelope, the two-centimeter joint between the loading bridge and the floor has a critical effect on airtightness. Attention must be paid to sealing this joint (Figure 7). The authors are not aware of any airtightness targets for movable loading bridges.

Figure 7: Detail, movable loading bridge with integrated sealing. A clearly visible air leakage only remains at door level.
(Source: Bauphysikkalender 2012/Calendar of Building Physics 2012)

TEST EXAMPLE

Figure 8: New school building in Luxemburg, cafeteria building “Public” with integrated BlowerDoor MultipleFan measuring system.

Building envelope = 15,000 m^2

Internal building volume = 45,000 m^3

Target value: $q_{50} \leq 1.25\ m^3/(h \cdot m^2)$

Test results: V_{50} = 7,000 m^3/h, $q_{50} = 0.5\ m^3/(h \cdot m^2)$, $n_{50} = 0.15\ h^{-1}$

Figure 9: During the BlowerDoor test in the building “Public”

Conclusion: The authors recommend discussing the target values for large buildings as pertains to setting a target value for newly planned large buildings of $q_{50} < 2.0\ m^3/(h \cdot m^2)$ in calls for tender and stricter requirements, e.g., determining a target value of $q_{50} \leq 1.25\ m^3/(h \cdot m^2)$ for office buildings.

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