AIRTIGHTNESS CONTROL DURING THE DESIGN AND CONSTRUCTION OF A MULTI-FAMILY RESIDENTIAL PASSIVE BUILDING

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Summary

The design of the air barrier system for a multi-family residential passive house in Prague was based on a series of preliminary airtightness tests. Its execution was controlled during the construction process, both visually and by means of airtightness testing in different stages of the construction process. A series of airtightness tests performed after completion of the building proved the compliance with the airtightness requirements for passive houses. In order to evaluate the air barrier system performance, these test results were compared to the values measured in a very similar building built without respect to the airtightness. Different airtightness test methods were used for the purposes of this project, which allowed comparison of their reliability.

Keywords: airtightness, passive houses, multi-family residential buildings

1 Situation

During the construction of a low-energy multi-family residential building, the developer decided to improve the target energy performance and finalize the building as a passive house. Figure 1 illustrates the state of the building at that moment. The load bearing structure was already erected as well as external walls and internal partitions. All the external windows and doors were already fastened to the building envelope.

The building was originally designed as a low-energy building. Thermal parameters of the building envelope as well as the heating system and ventilation system with heat recovery were properly designed in order to meet this target energy performance. Nevertheless, no special attention was paid to the building envelope airtightness.

2 Objectives

The developer demanded that the building matches the specifications of the passive house label as defined in [1], including the corresponding airtightness requirements ($n_{50} \leq 0.6\ h^{-1}$). Therefore, the original design solutions had to be examined and modified if necessary (in this contribution, only the modifications related to the airtightness are addressed). The achievement of the target airtightness had to be proved by means of measurement after completion of construction works.

Fig. 1 *Examined building, initial state.*
1 – elevator shaft, 2 – expansion joint

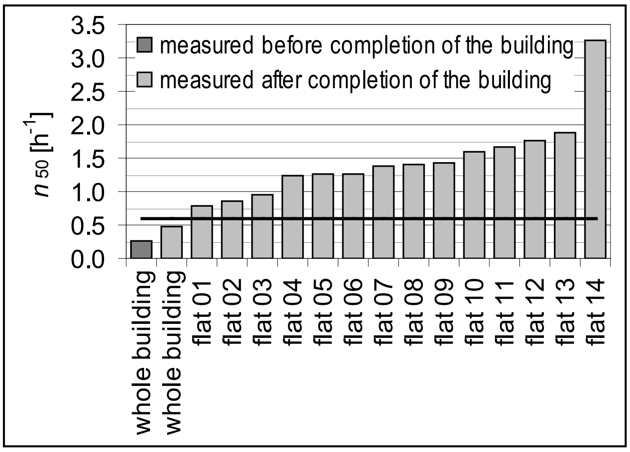

Fig. 2 *Overview of airtightness test results (selection)*

3 Approach, methods and results

3.1 Inspection of the design project and the state of the building

Firstly, the original design project was examined in order to identify the major obstacles which could threaten the achievement of the target airtightness level. The outcomes were verified in situ. The inspection work revealed numerous problems (critical, potentially leaky details and building elements – e.g. the expansion joint around the elevator shaft with a complicated geometry and limited access from the internal side).

3.2 Preliminary airtightness tests

In order to verify the significance of the major problems identified in the previous step a series of preliminary tests was performed before the modifications of the original design.

The results of airtightness test of the elevator shaft proved that the joints between the concrete segments are sufficiently airtight and therefore will not affect the overall building airtightness.

A simple qualitative test using the fog and overpressure in sanitary rooms proved a poor airtightness of penetrations of building services installations through the floor slabs (including the roof and the ceiling above the underground garage).

The airtightness of a selected flat in a similar building was examined experimentally. This reference building was built in the same development using the same technologies as the studied building, but without special attention paid to the airtightness. A series of tests performed using the progressive sealing technique proved a relatively high significance of some common leakage paths in the external wall (electrical boxes, window interface, joint of the floor slab and external wall, penetrations through the floor slabs). Still, these results indicated that an enhancement of the original design solutions would enable to achieve the target airtightness.

3.3 Design of the air barrier system

Based on the results of inspection works and the feedback from the preliminary airtightness tests, a new air barrier system was designed and documented, including detailed drawings and airtightness requirements for the potentially leaky building elements – e.g. the curtain wall with integrated entrance doors (entrance curtain wall). Design of airtightening measures for the expansion joint around the elevator shaft represented the most complicated task (use of special airtight polyurethan foam was necessary).

3.4 Control of the air barrier system execution

Besides a visual control of construction works related to the air barrier system, selected flats were tested at different stages of construction process. This approach allowed several defects of the air barrier system to be detected and repaired in time. The measured n_{50} values were included between 0,6 and 2,4 h^{-1} (in function of the stage of the construction process at the moment of the test).

Due to the coincidence with construction process, it was very complicated to measure the whole building envelope airtightness before completion of the construction works. Hence, the whole building airtightness was tested only once before the completion of the building, with the opening for the entrance curtain wall temporarily filled by means of a gypsum board structure. The measured n_{50} value was 0,26 h^{-1}. The difference between the whole building and particular flats test results may be assigned to the internal air leakage through the partitions between the flats.

3.5 Final airtightness tests

The whole building envelope airtightness test was repeated after completion of the building. The measured n_{50} value was 0,48 h^{-1}. The entrance curtain wall represented the most important leakage path due to unsuitable choice of product and installation method (the specifications of the air barrier system design project were not respected). The building was re-tested again with the curtain wall temporarily sealed. Then, the measured n_{50} value was 0,37 h^{-1}. It is still significantly higher than the whole building n_{50} value measured during the construction process. The difference might be partly explained by different preparation of the building for these two tests. However, the air barrier system was very likely damaged during the final construction works after the first whole building test (the defects remained undisclosed).

In addition, the whole building was tested with the entrance doors from the staircase to the flats closed. Based on the comparison of the whole building test results with different preparation (whole building, entrance curtain wall sealed, entrance doors to the flats closed), the distribution of the air leakage over the building envelope was roughly estimated (see table 1).

Tab. 1 *Estimated air permeability of different parts of the building envelope (at 50Pa)*

part of the building envelope	**air permeability q_{50} [$m^3/(h\cdot m^2)$]**
curtain wall with integrated entrance door	≈ 60
envelope of the staircase	2 ÷ 4
envelope of the flats	0,.2 ÷ 0,5

The air permeability of the envelope around the flats corresponds to the level commonly achieved in single family passive houses. This result proves a very good quality of the air barrier system in this part of building envelope which, however, does not contain complicated structural details. The poor airtightness of the envelope of the staircase is probably caused by the air leakage through the expansion joint around the elevator shaft (very complicated detail – see text above) and perhaps other potentially leaky building elements (staircase curtain wall, roof hatch). The causes of the excessive air leakage through the entrance curtain wall were explained in the text above.

Each particular flat was tested after completion of the building as well (for results, see figure 2). The high n_{50} values of particular flats (compared to the whole building n_{50} value) can be explained by significant air leakage through the internal partitions.

Finally, a nearly identical building of the same development built by means of the same technology, but without the respect to airtightness, was tested after its completion. The measured n_{50} value of 0,72 h^{-1} was significantly higher than the test result of the examined passive building, moreover it did not meet the passive house requirement.

4 Conclusions

The objective set by the developer ($n_{50} \leq 0{,}6\ h^{-1}$) was fulfilled. The comparison with "standard" reference building showed that it is unlikely to achieve this result without a special care to the building airtightness during the design and construction process. The approach and methods used in this project can be recommended in such cases (including preliminary tests). The experience points out that the major problems should be avoided in the early stages of the design process (e.g. it was possible to avoid the complications due to the leaky expansion joint by changing the position of the elevator shaft).

It was shown that the airtightness may change in the course of the building process. In this case, it deteriorated during the final construction phase, which proves the need of careful control until the completion of the building.

The significant internal air leakage was found to be a limiting factor for the use of so called sampling methods (estimation of the whole building airtightness from the test results of a sample of building parts, e.g. particular flats). The estimation of the airtightness distribution over the building envelope (based on subtraction of the tests results of different building parts) allowed the major leakages to be identified. The method used in this project was found beneficial despite its significant uncertainty.

References

[1] *TNI 73 0330 Simplified calculation assessment and classification of residential buildings with low energy demand for space heating – Multifamily residential buildings*. Preliminary technical standard, ÚNMZ 2010