A METHOD TO ENSURE AIRTIGHTNESS OF THE BUILDING ENVELOPE

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ABSTRACT

Several research projects have shown the importance of airtightness of buildings in order to ensure efficient energy use, good indoor environments, protection against moisture and general durability. The building industry in Sweden has shown interest in becoming a general method to support different actors to reach airtight building envelopes.

The purpose of this project has been to identify and develop a method to follow in order to design and construct airtight building envelopes. The method can be used by the building developer, designer and/or construction company and is a means of applying knowledge and experience from research and development projects to practical use.

Based on experience from several building projects and earlier research in the area of airtightness, this project presents a general method for the design and construction of airtight buildings, covering all aspects from initial formulation of requirements, through general and detailed design, to production and monitoring. The method is based on quality assurance through constant documentation, communication, inspection and verification, with the help of routines and associated checklists.

Experience from building projects where good airtightness has been achieved shows the importance of information and education. Appropriate and suitable information must be provided to a number of parties, such as designers, carpenters, electrical contractors and HVAC contractors. Another important factor is ensuring that requirements in respect of airtightness are clearly expressed and followed-up. Early measurement during the construction stage is one example of positive action to ensure good airtightness.

The routines, checklists, training materials, and tips for further reading or investigation that have been developed by the project are available on a website in order to make the material as available as possible to actors in the Swedish building sector.

Keywords: Airtightness, building envelope, method, requirements, monitoring, quality management.

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INTRODUCTION

There is a need for a method that can be implemented in the building process to achieve airtight buildings. There are experiences from the building process where airtight building envelopes have been reached, and there are also knowledge from research projects that can be communicated to the building industry to assist in the process to ensure airtight building envelopes. Example of airtight buildings where experiences has been collected are the buildings in Lindås, see Figure 1.

1. OBJECTIVE

The objective of the work of the project is to develop a general method for the construction of airtight buildings, covering formulation/expression of requirements, planning, design and construction. The method is based on quality management/assurance through ongoing documentation, communication, inspection and verification, using quality management procedures and associated checklists. The checklists provide a means of disseminating the results obtained and knowledge acquired for practical application.

The intention is that the method should assist those involved in the building sector, and particularly contractors, to ensure that a building meets the function requirements that have been specified. Properly drawn-up function requirements and quality management of the construction process provide favourable conditions for producing an airtight building.

2. IMPLEMENTATION

The work has been carried out in two stages. Stage 1 developed the quality assurance method, while Stage 2 tested it in a pilot project, with the results being thereafter evaluated. The associated training materials have also been tested in connection with starting a building project. Improvements have been made, based on experience from the pilot projects.

3. METHOD FOR PRODUCING AIRTIGHT BUILDINGS

3.1 Airtightness during early planning stage

Figure 1. Clear formulation of requirements provides the basis for successfully achieving an airtight building. The Lindås houses are an example of such a project, in which requirements were formulated and monitored.

The following procedures are intended to assist developers in their own work of deciding on requirements and monitoring their application in order to arrive at good airtightness:

The developer's procedure/checklist (can also be used by the developer's representative):

a) Decide on the required ambition level for the developer's own work.

b) For conversion/rebuilding projects, perform a survey/inventory.

c) Formulate requirements for an airtight building. This must include both technical requirements and those governing work/activities. See chapter 4.

d) Check/review procurement procedures and contract details in order to be sure that requirements are being correctly understood.

e) Appoint a person to be responsible for monitoring application of requirements and deciding the forms of monitoring.

f) If necessary: arrange information/training for those involved prior to starting work.

3.2 Airtightness during design stage

Figure 2. Penetrations through the sealing membrane can be avoided if the membrane is applied in such a way as to leave a gap for installation of the building's services systems.

The following is a procedure description/checklist to assist the designer's work of achieving airtight buildings, bearing in mind that it is not only this work that is important, but also communication of the necessary information to developers and contractors.

The designer's procedure/checklist for the design stage:

a) Appoint a person to be responsible for matters relating to airtightness during the design stage, with his/her work including this procedure/checklist.

b) Go through the requirements and intentions with the developer, ensuring that all are properly understood and accepted.

c) Provide necessary information/training.

d) Perform the design work and prepare documentation in accordance with checklists.

e) Perform internal checking of design documents in respect of airtightness.

f) Identify, plan and document critical production stages in conjunction with contractors. See Figure 2 as an example where the penetrations could have been planned for in a better wa.

g) Handing over to contractors: prepare a plan for airtightness during the production stage in conjunction with contractors.

h) Collect and put together all necessary documentation.

The following is a description of the procedure for the developer's monitoring of the work during the design stage. The developer's involvement is important and helps to maintain quality.

The developer's procedure for monitoring during the design stage:

a) Contact with the person responsible for airtightness aspects, and checking his/her internal communication of requirements, dissemination of information and provision of training.

b) Checking of documentation of materials to be used for air sealing purposes and of proposed designs.

c) Obtain confirmation that the contractor has carefully gone through the design documents.

d) Obtain confirmation, in conjunction with the contractor, that the contractor has identified critical tasks, and that an inspection plan for production/construction has been prepared.

3.3 Airtightness during production stage

Figure 3. An airtightness test (Blower-Door), looking for air leaks, provides indication of whether the requirements have been fulfilled.

The following is a description of the contractor's procedures/checklists for the work of delivering an airtight building, for which the contractor's quality of workmanship is important, as is communication with the designers and the developer.

The contractor's procedure/checklist for the production/construction stage:

a) Appoint a person to be responsible for airtightness-related work aspects at the site.

b) Go through the airtightness requirements.

c) Go through the design documents together with the designers, to discuss critical stages / details of production.

d) If changes are made, show that airtightness requirements will be met after the changes.

e) Draw up an inspection plan in conjunction with the designers.

f) Arrange internal information/training that also includes sub-contractors.

g) Work planning (before each new stage).

h) Preliminary airtightness testing and leak tracing. In Figure 3 a blower-door equipment is shown. Leak tracing can often be carried througt by a thermography in cold climates. Alternatives that are decribed and used in Sweden are measuring air velocity or using smoke to detect air leakages.

i) Final airtightness testing.

j) Feed back information/experience to the designers.

The developer's procedure for monitoring during the construction stage:

a) Contact with the person responsible for matters relating to airtightness and ensuring that he/she is providing all necessary internal communication of requirements, information and training.

b) Ensure that documentation from internal inspections is being prepared in accordance with the overall inspection plans.

c) Check documentation from early airtightness tests/leak tracing and from any resulting improvements/corrections.

d) Obtain confirmation/documentation from final airtightness testing that all requirements have been fulfilled. (This may possibly be done before expiry of the warranty period.)

3.4 Airtightness during operation stage

During the life of the building, the airtight layer is often inaccessible for inspection and maintenance, yet there are joints and structural components that may need maintenance or attention. If the building is extended or converted, or if new penetrations are needed, it will be necessary to ensure that the work is carefully performed, and based on careful design, in order not to destroy the airtightness of the building through unsuitable designs.

Procedure for maintenance of airtightness:

a) Check airtightness around penetrations (e.g. ducts into the roof space).

b) Check airtightness around window casements and frames and doors.

c) Note and investigate complaints concerning draughts or cold floors. These are often due to a non-airtight building envelope, and can generally be put right.

4. EXAMPLES FROM THE METHOD – REQUIREMENTS

The following are a number of suggestions as to how the developer might formulate requirements, who is responsible for fulfilling the requirements, and how the parties concerned should confirm that the requirements have been fulfilled. The developer can choose those suggestions that best match his ambition levels. Alternatively, the suggestions can be seen as starting points for formulation of other requirements. Just how the requirements for a project should be formulated depends on many factors, such as the choice of contract form.

The planning and design stage

Requirement no. 1: Appoint a person within the design organisation to be responsible for matters relating to airtightness.

Requirement no. 2: The aim of the design, in respect of airtightness, is to deliver the necessary conditions (supported by good quality of workmanship during construction) for ensuring that the building meets the airtightness requirement at a pressure difference of ±50 Pa. (Select one of the alternatives below.)

Alternative 1: Maximum air leakage as specified in the energy balance calculations for the building *.

Alternative 2: Air leakage through the building envelope not to exceed xx l/m²s *

* Requirement 10 specifies how airtightness is to be tested, and must be stated together with the requirement governing maximum permissible air leakage. It can be important in some cases also to include a requirement that specifies the required airtightness between different parts of the building (e.g. between fire cells or apartments). See also Requirement 10.

Airtightness requirements for windows and doors can be specified separately. They might be required to meet, for example, Class 4 airtightness requirement in accordance with EN 14351-1. Class 4 permits a maximum air leakage of 3 m³/hm²

at 100 Pa pressure difference. (This information is given by the window/door supplier.)

Requirement no. 3: The aim of design is also to ensure the necessary conditions for continued airtightness during the life of the building, through appropriate choices of design details, materials and combinations of materials. It must be known or demonstrated, and documented, that materials such as tapes, mastics etc. are durable when applied to the materials to which they are intended to be applied. It is also important that their adhesion is good under the conditions to which they will be exposed (e.g. temperature).

Requirement no. 4: Designs for airtight buildings must clearly include, show and describe detailing (in the form of drawings and descriptions), such as:

- How penetrations, leaks and holes in the airtight material can be avoided.
- How penetrations through the sealing layer should be made, where they cannot be avoided.
- In lightweight structures: how joints in the sealing layer are to be made.
- Connections around windows, doors and access hatches to roof spaces.
- Connections between joists etc. to the building envelope.
- Connections between outer walls / roof structure.
- Connections between tie beams / sloping roofs / braced walls.
- Connections between lightweight structures and concrete structures.
- Connections between steel structures, pillars, glulam beams etc.
- Connections of prefabricated elements.
- Structures in contact with the ground.
- Particular jobs and feasibility / method of construction to be agreed with the contractor.

The construction stage

Requirement no. 5: The contractor must appoint a person responsible for the building's airtightness. He/she will manage the work needed to ensure compliance

with the requirements, be responsible for the contractor's testing, and prepare and submit documented verification to the developer.

Requirement no. 6: Startup / **work planning** must be performed where specific tasks for airtight buildings are being planned in conjunction with the designers. An **own inspection plan (airtightness testing)** of technical features and workmanship must be prepared.

Requirement no. 7: Training of personnel at the site (construction, electrical, ventilation, HVAC personnel etc.) to be carried out in connection with start of work.

Requirement no. 8: Results from own inspections of technical solutions and jobs to be documented. The documentation must also describe how problems, defects, etc. have been dealt with. In the case of general defects, all persons concerned on the site must be informed.

Requirement no. 9: Performance measurements and leak tracing must be carried out at an early stage, as soon as the airtight layer or membrane has been applied and fixed, and when no further holes will be made in it. The need for repairs or improvements must be decided. The results are intended to document that no local leaks can cause future problems as a result of the positions and size of leaks. (Depending on just where leaks are, they can cause problems such as draughts, inward leakage of ground radon or local moisture problems in roof spaces.) For large buildings, parts of the building can be completed and airtight-tested at an early stage. Airtightness must be better than the requirement as set out below. Measurements must be made in several areas, as specified by the developer.

Requirement no. 10: Verification measurements must be made when the building envelop has been completed, and must fulfil the airtightness requirement at ±50 Pa pressure difference.

Alternative 1: Maximum air leakage as specified in the energy balance calculations for the building .

Alternative 2: Air leakage through the building envelope not to exceed xx l/m²s

Verification in small and large buildings: Test airtightness in accordance with EN 13829:2000, and report the results at least x days before the date of final inspection of the building.

Requirement no. 11: Repeat the confirmatory airtightness measurement as specified in Requirement 10 when the building's guarantee period expires, in order to confirm that the airtightness performance has not declined. The developer may also wish to consider including a requirement or conditions for monitoring the performance after a certain number of years.

Requirement no. 12: In the event of any changed methods, the contractor must show that airtightness requirements are being fulfilled, and that no other requirements have been overlooked.

CONCLUSIONS

If function and performance requirements have been properly formulated, and the physical production process is quality-assured, conditions are favourable for achieving an airtight building. The routines and checklists provide a means of applying the knowledge and experience from research and development projects to practical use.

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