AN EXPERIMENTAL STUDY ON THE VENTILATION CONTROL RELATED TO THE ENVELOPE OF A NEW AIRPORT TERMINAL

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ABSTRACT

Over the last decades, a great importance has been given to thermal insulation, in technological designing of building envelope.
Lately, a basic requirement of indoor air quality, strictly related to ventilation control strategies, has been highlighted.
Then, it is necessary to evaluate correctly, during the design phase, the air permeability of enclosures through validated methods, to assess new technologies through laboratory tests on prototypes and finally to verify real performances through on-site testings.
ICITE is developing researches and experiments to set up methods and instruments to evaluate in laboratory and on-site the permeability perfomances of windows and external walls.
The report will present the significant case of the on-site permeability evaluation of the envelope of a new airport terminal.
Performing testings in non-standards conditions forced us to consider and measure environmental conditions influencing the experimentations: air temperatures, humidity, wind velocity and pressures.
Particular attention was drawn to the "ad hoc" construction of an airtight chamber of significant dimensions, 2.4 x 4.8 m; such a chamber has been designed to isolate the panels of the sample area from the external structure, to obtain homogeneus surrounding conditions and to be flexible during assembling operations.
The data concerning all the physical measurements, have been acquired and processed by means of an appropriate software and functional checking procedures have been defined for the airtight chamber and measuring instruments.
The adopted methodology may be used to define pre-standards concerning on-site test methods.

KEYWORDS

On-site tests, Airtight chamber, Tests performed, Air permeability, Watertightness, Wind resistence, Environmental influence, Airtight chamber

INTRODUCTION

Over recent decades, great emphasis has been placed in technological design, in particular that of the envelope of a building, on the heat insulation requirement. In actual fact the need for basic indoor air quality has recently been expressed, directly linked to correct management of ventilation. It has therefore become increasingly necessary to assess the air permeability of closure elements by calculation at the design stage, by laboratory tests in the prototyping and technological innovation phases and by on-site test techniques during building.
The aim of the experiment presented on the following pages was to focus on an emblematic case, for which the need to obtain significant figures on actual performances in working conditions means that the tests have to be carried out in situ.
Against this background, ICITE, which has worked for years in the area of performance testing of external closure systems and components, both in terms of certification and research and tests, always takes the opportunity of transferring its knowledge and experience, gained in traditional environments, towards new areas capable of providing a further boost to the constantly advancing technical and scientific process.
Although for around thirty years at the ICITE laboratories work has already been performed on frames and façades in order to support the relevant industry and assist end users, the request made to the Institute by the Italian Transport Ministry to perform tests *in situ* on panels of the architectural system of cladding of façades, used in the building of the new "Malpensa 2000" air passenger terminal, was welcomed with considerable enthusiasm, in view of the possibility of assessing the performance features of the test elements in the light of the additional variables which go beyond the boundaries of the laboratory.
Moreover research efforts are currently oriented towards the subject of natural ventilation and the dual commitment to developing new devices capable of automatic regulation, according to the difference in pressure between the interior and exterior, and that relating to the need to increase awareness of national legislators on the problem of proper ventilation: this theme will however be dealt with specifically in the paper entitled "Devices for controlled natural ventilation".

THE EXPERIENCE OF ON-SITE TESTS

The eminently experimental activity of ICITE was performed on the architectural system of cladding of the façades during installation of the new "Malpensa 2000 air passenger terminal, whose samples, chosen for performing the tests, were located in the area of the forepart of the south satellite, on the linking tunnel entrance side, in the northern zone.
The cycle of tests was carried out on two different samples, one consisting of seven blind panels and one with windows and measuring 120 x 120 cm, and the other of eight blind panels of the same size as the previous ones.
Firstly, the aim to test the real behaviour of the panels in relation to their air permeability, watertightness and wind resistance, without ad hoc standards, entailed the use of the test methods indicated in the harmonised standard provisions UNI EN 42 - 86 - 77, aimed specifically at "Methods of tests on windows". In this respect an important aspect of the entire experimental layout of the procedure concerned the choice of criteria for application of the aforementioned standards to the façade cladding systems, given the need to guarantee the most accurate interpretation.
Furthermore the procedures for implementing the tests on site involved further areas of attention: from the control of environmental implications (temperature, humidity, barometric

pressure etc.) to the setting-up of an airtight chamber, of considerable size, for performing tests on the sample taken from the surrounding structure.

More particularly the airtight chamber was built to incorporate a significant number of panels making up the sample, without weighing down the surrounding structure, observing identical conditions at each boundary point and adopting flexible methods in order to facilitate operations of attachment and removal.

The test instruments

In order to carry out the tests the instruments *normally* used in the laboratory were adopted; nevertheless, in order to ensure maximum suitability for carrying out the standardised performance tests required, the equipment underwent a series of working tests, performed with the aid of a calibrated tank and according to the procedures described in the *Icite Report* dated 14 November 1997.

Setting up tests in situ requires further additions to the laboratory instruments, given the influence of the external and internal environmental conditions on the tests themselves.

In particular the pressure difference set by the test equipment can be influenced, in certain conditions, by those pressures differences imposed by the wind and the stack effect. In turn the air flow rate measurement may also be influenced by the difference in density of the air compared to the laboratory reference conditions.

In order to keep these potential influences under control during the tests performed at the Malpensa site, the environmental conditions were constantly monitored.

The data relating to instrument measurements were acquired and the tests controlled by developing a computerised system consisting of data acquisition hardware interfaced with a personal computer and of specially developed softwares.

Airtight chamber

For the laboratory tests the airtight chamber is built by inserting the sample (window/vertical closure element) in a support frame, to be attached to the test wall, in order to achieve the set conditions of pressure/vacuum in the area created. The frame, prepared ad hoc, must be sufficiently rigid to withstand the test pressures without inducing deformations in the attachment or bending stress in the sample. Packing between the test wall and the frame ensures airtightness.

In the case of tests on site, since the sample is incorporated in the surrounding structure, the chamber was mounted externally and attached to the sample in order to reproduce the same conditions described for the laboratory.

The airtight chamber used at Malpensa for both samples, measuring 4.80 x 2.40 m, was mounted on the façade section chosen as the test sample, with seals and packing between them. Even pressure was exerted on the packing for sealing purposes.

The chamber was positioned on the sample by means of 10 threaded bars, with diameter of 14 mm each, of which six were buck-attached on the vertical upright of the structure, while suitable procedures were adopted for the other four to ensure perfect attachment of the frame to the façade elements. The bars were passed through the panels outside of the test area and spaced by the horizontal and vertical joints of the system.

The exterior of the airtight chamber, i.e. the side opposite that of the sample, was built in iron and wood for roofing purposes. 32 nozzles were attached on the internal part to water the sample during the watertightness tests and supported by a square-mesh tubular grid, measuring 60 x 60 cm, for feeding water to the nozzles, according to Method 2 indicated by the standard UNI EN 86. This structure, consisting of 2 panels in silicone-coated wood screwed to the iron support grid, was then attached to the remaining part of the airtight chamber by means of 12 threaded bars after inserting the packing.

Finally, in order to prevent the weight of the chamber (around 700 kg) from bearing down on the area surrounding the sample, a support structure resting on the scaffold was also provided.

The procedures of testing and calibrating the airtight chamber were performed in the laboratory.

In addition to the flow sensor fitted to the equipment, a hot-wire anemometer was used, including a support for measuring directional air flows, inserted in the air feed conduit, to check that, through the effect of a set pressure, there are no significant leaks from the joints of the airtight chamber.

The openings of the chambers were also calibrated by various air permeability test cycles to bring the flow rate measurement field within the range of greater precision of the instruments used; the leaks, in the case of the panels, being distinctly smaller than those normally measured for window and door frames.

The tests performed

UNI EN 42, UNI EN 86 and UNI EN 77 represent national implementation of the standards processed and approved by the European Standardisation Committee.

The common aim is to define the methods to be used in performing tests for checking the performances of windows, considered as finished products and in their normal conditions of use.

Air permeability - UNI EN 42

The air permeability of a window, or of a vertical closure element, refers to the specific property of allowing air to pass through when subjected to a differential pressure. It is characterised by the air flow rate expressed in m3/h according to pressure.

With reference to the tests performed at the Malpensa 2000 airport terminal, the air permeability of the first sample was measured by adding the permeability of the window frame module to that of the blind modules. In this respect the leaks not depending on the sample were measured, appropriately sealing the joints of the window frame module and those of the blind module.

By feeding smoke into the airtight chamber, at a constant pressure of 600 Pa, a test was performed on the actual sealing which did not reveal smoke leaks.

On the basis of standardised methods, the permeability tests were carried out after applying 3 pulses of air pressure, lasting approximately 1 second and with a pressure of 500 Pa. Positive pressures were then applied, gradually increasing at minimum intervals of 10 seconds up to the maximum pressure of 600 Pa, according to the following intervals: 50, 100, 150, 200, 300, 400, 500, 600 Pa and the reverse sequence.

The first test produced the leakage values relating to the system (air feed conduits, calibrated holes in the airtight chamber etc.).
The second test on permeability of the system and of the window frame was carried out after removing the sealing attached to the window frame module. After also having removed the sealing from the joints between the modules, the third test was performed to measure total permeability of the sample.
By applying the appropriate differences the permeability of the sample was calculated both in relation to the part with a window and the blind part.
The second sample consists of blind modules alone therefore its air permeability is given by the permeability alone of these modules. In this respect the leaks which do not depend on the sample were measured, appropriately sealing the joints between the panels, then the first air permeability test was performed, calculating the system leakage values.
The second test, performed after removing the sealing, allowed total permeability (sample and system) to be measured.

Watertightness under static pressure - UNI EN 86

The watertightness of a window is expressed as its capacity, when closed, to withstand water infiltration, while the watertightness limit is represented by the maximum pressure value, achieved during the test, at which the watertightness conditions remain.
To perform the test the sample has to be watered with a quantity of water equal to 2 litres a minute per square metre, first without pressure and later with pressure increases at regular intervals. For the first interval, lasting fifteen minutes, watering is carried out at zero pressure while in the subsequent intervals, lasting five minutes each, the pressure in the airtight chamber increases up to 500 Pa and later with increments of 250 Pa to the agreed value.
In the case of the tests performed at Malpensa, the test pressure required by the specifications for testing watertightness was 300 Pa, therefore for the first sample the watertightness of the window frame module and of the joints of the blind panels was tested, and only the joints for the second sample.
The results obtained from the tests performed, whose publication is the sole responsibility of the client organisation, confirmed that there is no correlation between the air permeability and watertightness of an element. Although the test samples provided negligible air permeability values, even coming within the tolerance range of the equipment, the watertightness tests effectively indicated the critical points of the system.

Wind resistance - UNI EN 77

Wind behaviour is characterised by means of a complementary series of tests, aimed at assessing the effects on the sample element in terms of:

- ♦ presence of admissible deformation
- ♦ retaining of functional features
- ♦ user safety.

In this respect the admissible deformation was evaluated by applying a series of instruments (transducers) capable of detecting the displacement values in the points considered typical. The two samples were monitored by taking account of the fact that the joints being tested are those which work in real installation conditions and, as a result, the joints at the boundary of the sample are not to be considered.

For the window frame module the deformation of the glass and frame was measured, while for the blind panels logical preference was given to the points near the joints, chosen in mirror positions on two adjacent panels divided by the crosspiece of the support structure and on the actual frame which incorporates the panels.

The test cycle was considered to have ended when the final air permeability test indicated, at a pressure of 100 Pa, a variation in permeability no higher than 10% + 0.1 m3/(h.m) in relation to the original test performed and in accordance with standard regulations.The safety requirements mean that the samples tested are stressed, as a last resort, by bursts of pressure of 3150 Pa. In particular, for performing this test, the value of the burst was achieved in approximately 1 second and maintained for around 3 seconds.

Environmental influences

As mentioned previously, in on-site tests the pressure difference set by the test equipment can be influenced by those pressure differences imposed by the wind and heat forces stack effect. The measurement of the air flow rate can in turn be affected by the difference in air density compared to the laboratory reference conditions.

Simultaneously to the tests, the internal and external environmental conditions, which could affect the tests themselves, were measured: internal and external temperature (°C), internal and external relative humidity (%), wind speed (m/s) and barometric pressure (kPa).

More particularly the air flow rate measured on site can be adjusted to take account of extreme environmental conditions and return it to the laboratory reference conditions. This becomes necessary when the density of the air during the tests on site differs significantly from that usually found in the laboratory.

From the analysis of the average environmental conditions measured at the test site it was possible to evaluate a maximum correction term for the air flow rates according to the difference in air density compared to the laboratory reference conditions, of negligible extent.

FINAL CONSIDERATIONS

The experience of MALPENSA 2000 has enabled ICITE to experiment instruments and methods aimed at on-site tests, which will in the future be able to back standard proposals.

Likewise the same experience opens the way for further consideration linked to the strict need to assess on site the performance of special building structures, such as the case of the air terminal.

In the first place the comparison between the experience of past years gained in the laboratory and the tests performed on site suggest the following considerations:

- calibration in the laboratory and on-site working tests on the instruments and airtight chamber enable overall control of the data measured and therefore of the outcome of the tests;

- the design of the airtight chamber must take account of the technological aspects of the test samples, linked to structural questions, of the modular nature of the panels and operation of the joints;
- measuring the boundary environmental conditions of temperature, humidity and wind speed enable possible influences on the pressures due to the wind and stack effect and on the variations in air density to be kept under control;
- careful analysis of the "real" conditions of installation of the test samples allows constructional defects and non-conformity of the technologies in relation to the experimental laboratory set-ups to be revealed;
- in order to simplify the phases of assembly of the experimental set-up the instruments for the on-site tests must be compacted and made easily transportable, at the same time maintaining the necessary instrumental precision;
- given the working difficulties found in a site situation, the measurement instruments should be kept independent of the test conditions.

As far as the second aspect is concerned, regarding the required test in situ of the performance of closure elements for special structures, the case of the air terminal was chosen emblematically as, due to the fact that it is characterised by large spaces and considerable proximity to sources of high environmental and noise pollution, it means that the data obtained from the tests are as realistic as possible.