VENTILATION STRATEGIES OF A RESIDENTIAL DISTRICT ON RESTORATION: ANALYSIS OF TECHNICAL SOLUTIONS AND COMPARATIVE EVALUATION

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ABSTRACT

Within an Italian Experimental Programme an interdisciplinary research for the retrofitting of some residential buildings in the surrounding of Florence has been carried out. The activity of the experimental research concerns the methodological and scientific support to the technical solutions for the restoration of two buildings. The buildings' typology with central gallery and single face dwellings is the cause of bad ventilation and poor indoor air quality (IAQ) in the rooms and, consequently, is the cause of other problems related with an insufficient air exchange rate: odours and vapours stagnation, vapours condensation on cold walls, etc. In this paper preliminary results concerning IAQ improvement by using suitable ventilation systems are reported and discussed.

KEYWORDS

Ventilation, Indoor Air Quality, systems' assessment.

INTRODUCTION

Within an experimental programme an interdisciplinary research for the retrofitting of some residential buildings in a suburban district in the surrounding of Florence has been carried out by the Department of Technology. The suburban district was built in the '80 and consist of four buildings with a total of 140 dwellings. Exterior walls, dividing walls, floor slabs and staircases of the six storey buildings are made of prefabricated concrete elements. The walls of the distribution gallery are made of a double plaster component with an inner court for technical equipments; dividing walls between different dwellings are made of plaster as well.

The typical building has a N-S oriented main axis; the building typology is with central gallery distribution and single face dwellings, westward or eastward. As a result of this, in the mean belt of the building, near the inner court, are located kitchens and bathrooms; the second only being equipped with mechanical exhaust systems. In each building there are three typical apartments: 2, 3 and 4 rooms with 45, 70 and 90 m^2 (see fig.1). The experimental programme carried out during 2001 and 2002 involves the restoration of two apartment buildings; the activity of the research concerns the methodological and scientific support for the buildings restoration, as well as the monitoring of the buildings environmental parameters before and after the retrofitting actions. General aim of the research is the architectural restoration and the improvement of comfort and IAQ of the buildings. The Environmental Physics

HYPERLINK

Laboratory for Building Quality (EPLBQ) of the Department of Technology has been entrust with the IAQ improvement of some dwellings. In this work preliminary results of the experimentation carried out by the EPLBQ are presented.

METHODS

Building typology based on a central wide gallery distribution arouses great crossed ventilation problems inside the dwellings owing to the lack of double face of the building. Main problems pointed out in these buildings therefore are poor IAQ, odours and water vapour stagnation, as well as possible condensation on cold walls. Not even extremely large windows make up for the negative effects due to the building depth that forces the arrangements of the rooms in the dwellings. These problems could be solved by using suitable ventilation systems. The methodology used consists of the following phases:

1. analysis of the IAQ problem in the buildings studied through the determination of critical factors regarding rooms ventilation and through indoor air quality monitoring;
2. critical analysis of different kind of ventilation systems available and their comparative evaluation; determination of ventilation standards that have to be met;
3. determination of ventilation systems suitable for the specific buildings studied on the basis of performance criteria determined (efficient application of ventilation air, efficient energy use, costs, reliability);
4. IAQ monitoring after application of the ventilation system chosen, and agreement with Italian ventilation standards.

In this paper only phases from 1 to 3 are discussed.

RESULTS AND DISCUSSION

From on the spot investigation of the suburban district and from conversations with the occupants, main critical factors related to the buildings typology and the dwellings characteristics have come out. Main problems underlined by the occupants are:

- total absence of windows in the bathrooms;
- almost total absence of air flow rate in the dwellings: this gives rise to kitchen odours stagnation, condensation problems, high humidity, and high air temperature in hot seasons;
- environmental parameters don't fulfil comfort conditions at all;
- boiler placed in the kitchen instead of in the loggia;
- bad performances of the existing local exhaust systems: from bathrooms air exhaust system odours come in from other dwellings;
- in general, the obsolete technology of the buildings and of the technical equipments doesn't allow easy maintenance and/or substitutions;
- poor air tightness of the windows and of their boxes;
- bad thermal and acoustic insulation;
- not proper use of the habitable spaces: while living areas are very small and not well arranged, distribution gallery is very large, bad ventilated and quite dark.

In the buildings studied one of the most representative dwellings has been monitored, selected on the basis of orientation, IAQ problems, disposability of the occupants to store instruments, etc. For the no stop monitoring of microclimatic parameters (air temperature, surface temperature and relative humidity) some data loggers have been used. All probes and sensors have been programmed to acquire and memorize data every hour; data have been then transferred to a PC and elaborated in spread sheets with graphs, diagrams, etc. Indoor and outdoor monitoring has been carried out for one month in each season. Straight the most significant results about a 2 rooms apartment westward are summarized.

During winter conditions, indoor air temperature was contained within the range 17-23°C with maximum values when the heating system is switched on. Indoor relative humidity (RH) values fall within the range 25-58% with maximum values during lunch time because of water vapours generated in the kitchen. During summer period of monitoring, outdoor temperature reached maximum values of 36°C in the afternoon (17.00) and minimum values of 20°C in the early morning (5.00). Outdoor surface temperature of the flat roof remained above outdoor air temperature of about 1°C, reaching maximum values of 60°C when irradiated directly from the sun (13.00). Indoor air temperature ranged from 29°C in the morning (7.00) to 35°C in the night (20.00); the lowering of the external thermal wave was of 1.5°C while the phase delay was of about 3 hours. Indoor surface temperature of the roof was always lower then corresponding indoor air temperature of about 1°C, reaching the maximum value of 34°C during the night (20.00), when indoor air temperature is very high, and minimum value of 29°C during the morning (10.00). Outdoor RH ranged from 13% (12.00) to 84% (6.00), while indoor RH ranged from 27% (19.00) to 54% (10.00).

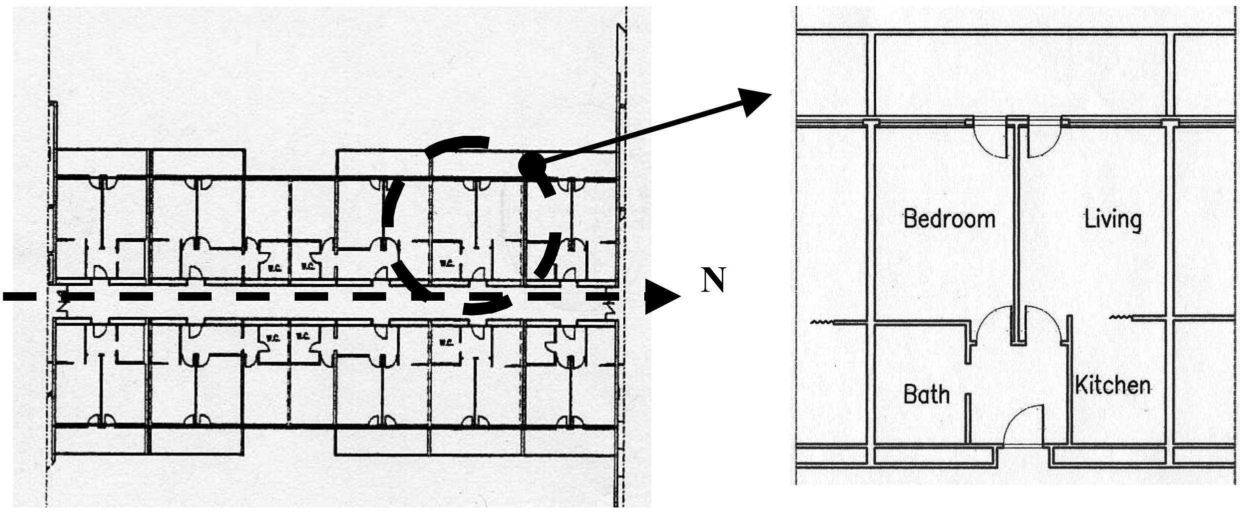

Figure 1: Extract from building plan and particular of the 2 rooms apartment monitored.

Critical analysis of ventilation systems is carried out by the classification of the systems including their descriptions, the characterisation of the system properties, their efficient energy use, cost and reliability. The properties of the systems are assessed regarding their applicability to the case study (see table 1).

Main combination of provisions for the ventilation systems are the follows:
- Mechanical Supply + Natural Exhaust (MS+NE)
- Natural Supply + Mechanical Exhaust (NS+ME)
- Natural Ventilation (NV)
- Mechanical Controlled Ventilation (MCV)

Objective of the chosen ventilation system is to create a main flow from the outside into habitable rooms (living room and bedroom) which overflow to service rooms (kitchen and bathroom) before being exhausted.

The system is made up of air inlet devices placed on the upper parts of the window boxes and vertical ducts, applied to service rooms, which create exhaust flows by using one mechanical fan, every five dwellings, placed on the roof. The flows per room with fixed window devices is controlled by relative humidity. The properties of the ventilation system are listed below:

- a continuous automatic control of the supply vent is needed to ensure adequate flows of outside air that would otherwise vary according to the prevailing weather conditions; therefore a humidity controlled ventilation systems has been chosen in order to provide ventilation rates commensurating the indoor vapour loads;
- the system is also equipped with some grilles to assure air flows through doors;
- vertical exhaust ducts are fitted into the inner courts along the gallery between the dwellings.

TABLE 1
Critical classification of ventilation systems

Ventilation system	Efficient application of ventilation air				Efficient energy use	Cost analysis		Reliability
	Local applicability	IAQ control	Flow rate adjustability	Air flow pattern		Installation	Operation	
NV	+	-	o	-		+	+	+
NS+ME	+	+	o	o	+	+	+	+
MS + NE	+	-	+	-	+	-	o	+
MCV	-	+	+	+	o	-	-	-
Legend: + good, o neutral, - bad								

The system fits into Italian technological tradition which eases the introduction and the experimentation of advanced versions. In summary these consist of:

- a MCV system which provide ventilation rates commensurating the strength of human-originating sources; a carbon dioxide and/or relative humidity controlled ventilation fulfil this requirement but entails a mechanical inlet and outlet, so that some air inlet ducts has to be set up in the dwelling. The CO_2 and RH sensors are based on the assumption that carbon dioxide and the humidity generated by human activities (respiration, cooking, personal hygiene, etc) are mainly representative for the indoor air pollution;
- the MCV system also allows both the local air flow regulation and the application of a heat recovery system on the exhaust air;
- the auxiliary energy for the exhaust fan could also been provided by a Photovoltaic system.

The air flow designed for the dwellings consists of 1 air change rate per hour (ach) in day time and of 0,5 ach during the night, while the air change for the blind bathrooms consists of 6 ach in day time and of 3 ach during the night.

In order to evaluate the system performance, the properties of the system itself have been critically analysed. The characterization of the system properties includes: efficient application of ventilation air, efficient energy use, costs, reliability.

Efficient application of ventilation air is evaluated from the definition of some others parameters, such as: local applicability, IAQ control, flow rate adjustability and air flow patterns.

Local applicability, that is the ability of the system to distribute the ventilation air, may be expressed by the answers to some fundamental questions related both to the rooms typology and to the ventilation system as a whole (see tab.2). As this ventilation systems is a natural supply and mechanical exhaust one, it is not possible to control air quality, air temperature and relative humidity. Nevertheless air exhaust from kitchens and bathrooms assures some air purification through air dilution. Even if at the moment the systems is not designed to be locally controlled, it is interesting to assess the ability of the system advanced versions to adjust the flow rate to the variable demands per room.

TABLE 2
Evaluation of local applicability of the ventilation system

	All rooms	Habitable rooms*	Service rooms**	
Which location can have its own provision for directly supply fresh outside air?		x		
Which location can have its own provision for air exhaust (directly or via a duct) to the outside?			x	
Which location are provided with provisions for air supply from the other rooms?			x	
Which location are provided with provisions for air exhaust to other rooms?			x	
As there are air exchange between room spaces, are the main sources of pollution in these rooms comparable?	Main sources of water vapours are the service rooms, while other pollutant (VOC, CO_2, etc) are mainly produced in the habitable rooms.			
What is the change of flow-reversion through ventilation provisions due to weather changes ?	none	rare X	regular	often
What is the change of flow-reversion through ventilation provisions due to other measures?	none X	rare	regular	often
Are the main ventilation provision for: ▪ fresh outside air supply ▪ direct exhaust to the outside ▪ air exchange between rooms to be operated separately per rooms?	none X X X	rare	regular	often
Notes: * dining room, bedroom; ** kitchen, bathroom, store-room				

The adjustability of the flow rate can be assessed by the answer to the questions reported in table 3.

One of the main objects of the restoration of the dwellings was to obtain the most efficient application of ventilation air within the rooms. This can be achieved when the fresh air is introduced directly into the occupied zone (living and bedrooms), and when the air flow expels all contaminant from the room with a minimum of dispersion. This property of the ventilation system is expressed as “ventilation efficiency” or the “coefficient of air performance”. Essential factors that has been assessed are: the location of the air supply, the velocity and the turbulence of supplied air, local exhaust near pollution sources.

In order to evaluate efficient energy use of the ventilation system the following factors has been evaluated:

- auxiliary energy need (total installed electric power demand for transporting and controlling the ventilation air) expressed in kW;
- on which flow rate is this power demand applied, expressed in m^3/h.

The estimated costs for the ventilation system include components, installation and maintenance. If a MCV systems equipped with air heating was settled, extra costs for preheating air (even with heat recovery) should be considered. On the other hand, even alternative energy gain devices can contribute to satisfy the ventilation system’s energy needs. Finally, the yearly costs for operating the ventilation systems has to be assessed with regard to maintenance, servicing, total energy demand and compared with the estimated life-cycle of the ventilation system’s main components.

TABLE 3
Adjustability of the flow rate

Are the ventilation provisions designed to provide the basic flow rate to the variable demand per room (according to the national standards?)							yes	no
Give the specific range of design values	Flow rate (m^3/s per)						opening area (m^2)	duct
	ach	room	person	window area	floor area	heat load		
Habitable rooms								
Kitchen								
Bathroom								
w.c.								
Whole dwelling								
Combustion apparatus								
Control used to adjust the set point of ventilation provisions to changing ventilation needs: ▪ all habitable rooms ▪ living ▪ bedroom ▪ kitchen ▪ bathroom	none	manual	timer	air temp.	RH	CO_2	others	
Legend: S: supply air; E: exhaust air								

Finally, even if is extremely difficult to classify ventilation systems as to their reliability, some possible critical parameters can be suggested. In summary, they are: number and type of system components, possible commissioning need for the ventilation system, operating instruction simplicity, user friendliness.

CONCLUSIONS AND IMPLICATIONS

General aim of this research was the architectural restoration and the improvement of comfort and IAQ of some residential buildings in a suburban district in Florence, Italy. The buildings' typology with central gallery and single face dwellings appears the cause of bad ventilation and poor IAQ in the rooms. In this paper preliminary results concerning IAQ improvement by using suitable ventilation systems are reported and discussed. In order to evaluate the ventilation systems performances, their properties have been critically analysed. The characterization of the system properties includes: efficient application of ventilation air, efficient energy use, costs and reliability. The used methodology provides for another phase concerning the application of the chosen ventilation system and the monitoring of the thermal and hygrometric conditions in the restored dwellings. Finally, when a ventilation system is introduced in a naturally ventilated building also the spaces of the vertical air exhausted ducts have to be carefully considered.

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