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THE RELATIONSHIP COMFORT - ENERGY - IAQ

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ABSTRACT. This paper starts from the point that indoor air quality problems are not a fatality. Much can be done in order to prevent IAQ problems starting from the very brief for the building design. The balance between energy use in buildings and IAQ and comfort must be, before all, a compromise between building physics and energy. There may be a need for systems with growing level of sophistication, but it is up to the designer to select the most appropriate means for the required objectives.

Comfort is considered under a broader perspective than just thermal comfort. The case of the free-running buildings, as it is common in many regions, is taken as an example of the need for a better understanding of the comfort issue under transient conditions. The energy use in those buildings calls for a larger participation of the environmental energy in the building design, including the use of natural ventilation. Then, the IAQ issue, when addressed, tends to have smaller relevance and, in any case, a larger dependence on outdoor air quality than in the conventional air condicioned buildings.

New comfort information must be given to the designers, in particular for the case of free-running buildings, both in cold climates, for the summer period, and in warm climates, for all seasons.

1. INTRODUCTION

The problem of the quality of the indoor environment has been addressed through several different perspectives. The threshold limite values used for the industrial environments are orders of magnitude higher than the concentration values issued as air quality guidelines by WHO (1). This seems to suggest a clear separation among the situations where the indoor environment represents an occupational or an hygiene and health problem from those where one is concerned with a problem of comfort.

However, some standards, like ASHRAE ST-62 1981(2), bring together objective and subjective criteria to define indoor air quality stating that acceptable indoor air quality is "air in which there are no known contaminants at harmful concentrations and with which a substancial majority (usually 80%) of the people do not express dissatisfaction". It implies that a lower level of concentrations of contaminants, not necessarily harmful for the health, may have some consequences upon comfort.

The contamination of indoor air is due to a large variety of sources such as the occupants, fabrics and other building materials, the outdoor air and even the HVAC systems themselves. The tightness of the

Comfort, particularly in the 60s and in the 70s, was mainly a thermal issue (air temperature, radiant temperature, humidity and air velocity) but air quality, lighting and background ambient noise also gradually became important issues.

Comfort has been largely studied, particularly during the past thirty years. However one must say that this does not mean that comfort is a well known parameter and that what is known on comfort hardly covers all environmental conditions and responds to all personnal or behavioural situations.

One could say that comfort has been mostly seen so far as a quasi-steady state issue, starting from the experience of colder regions where spaces tended to be well insulated and sealed and where people were subjected to steady environments, either under heating or cooling processes, for a relatively long period. But it was reported that the owners of passive solar buildings in the USA, in the late 70s and early 80s, accepted the considerable temperature swings of the indoor air temperature quite well. That raised the question of how comfort is much more than just a thermophysiologic process and how comfort can be characterized under transient heating or cooling conditions. The case of the free-running buildings is a common example where there is a lack of information concerning comfort under transient conditions and consequently on how to deal with the comfort issue in order to be able to convey the appropriate information on comfort for designers of such buildings.

2. ENERGY IN BUILDINGS

Energy is needed as a decisive contribution to fulfill some requirements for comfort, namely thermal (heating and cooling) and lighting comfort. For some time, a great emphasis was placed on thermal comfort. Daylighting only recently regained importance as a peculiar aspect of lighting comfort. This does not mean any refusal of the benefits and potentialities of artifitial lighting. On the contrary, it simply puts the accent on the specific benefits that daylighting can provide whenever applicable, bringing together both natural energy and visual comfort advantages.

But the experience of energy as a scarce resource in the World only seems to have been understood since the early 70s, when some political crises and cartel "games" called for more rational attitudes towards energy use.

The use of energy in buildings became a problem of energy conservation under two main perspectives: attenuation of energy consumption and diversification of the primary forms of energy. In the beginning, economics, under both macro- and micro- perspectives, supported the rationale for energy options such as heat pumps in France, an electricity paradise, and increasing levels of cost-effective insulation in the colder regions. Nowadays, when the energy situation became somewhat more relaxed, another crucial issue was raised: the environment. The use of fossil fuels is being blamed for problems relating to global warming and some fluorcarbons used in refrigerating equipment have been identified as harmful for the ozone layer.

The attenuation of the energy consumption has asked for the reduction of energy needs for heating and for cooling, rendering envelopes better insulated and better sealed for reducing the ventilation rates. The variation of recommended ventilation rates has pointedly changed in close response to changes in energy prices. IAQ has been seen mainly as a consequence of energy use. In fact, IAQ has to do with building envelopes, as a way of promoting energy economy, the use of some building materials and the lack of appropriate maintenance of the HVAC systems have given a particular dimension to the IAQ problem. The recommended solutions are source control, avoiding or attenuating the emission of contaminants,air cleaning, and, the most common, the use of ventilation. While some sources of contaminants, such as the occupants, cannot be avoided, others can be eliminated or reduced, through appropriate choice of materials, and, in particular,the case of the systems themselves, through an adequate maintenance.

What seems to be somehow forgotten is that IAQ is not a fatality for neither the northern nor the southern latitudes, whichever differences in climatic conditions and energy strategies between those regions. The IAQ issue must be addressed at the design stage.The point to make is that the IAQ problem must not be approached under the some perspective as, e.g., the stability problem in earthquake-prone areas. In the latter case, nothing can help but to be prepared for the fatality to happen.For the IAQ problem, the same happens with the cases of contaminants that cannot be avoided, such as the contaminants derived from occupancy or particular necessary industrial processes. But in all the other cases, there are many options to prevent the contaminants. An essencial role of the design process is to create the conditions to prevent the contaminant sources before addressing the cleaning strategy (filtering) and the dilution strategy (ventilation).

That is why the current knowledge about IAQ should be brought as an essencial feedback for the design process from the very brief for the building design. The objectives of every building should be analysed and the strategies for comfort and for the use of HVAC systems must be discussed from the earliest stage of the design process taking into account the different climatological caracteristics and the different energy options, namely those related with the climate. As stated in (1), "Several sources of air pollutants have unique national components that are best subject to national control procedures. For example, indoor ventilation and heating systems, major determinants of indoor air pollution levels, are heavily influenced by the geographical location of the building".

It is out of question that the more demanding the indoor environmental conditions are, the more sophisticated the system must be and, moreover, the more accurate the controls and the maintenance routines ought to be. However, technological advances do not necessarily mean that they shall be used everywhere: it simply means that the designers have a larger spectrum of design options to consider. Let us consider as an example the case of an air conditioning system in a building in a region with a mild climate. As there are potentially longer periods of intermittent functionning, it is more likely to require stricter maintenance of the HVAC system for obvious reasons, because, if not in use, it may be a source of contaminants that would not appear in the building if that particular type of system was not the one to be installed.Therefore there a reason to weight the pros and the cons of installing some sort of HVAC system is in this case.

The climatic conditions may allow for naturally obtained comfortable indoor environments, in many cases without any auxilliary systems.Therefore, understanding comfort is necessary for a good or at least, an adequate choice of a system for a given building. That is why one could say that the balance between energy use in buildings, IAQ and comfort is, in first place, a compromise between building physics and energy for a particular climate.

the quality of the outside air, but it is mostly related with the presence of internal sources of contaminants in a rather closed space. That is why energy conservation measures such as reduced heating/cooling loads, low ventilations rates and minimal outside air ventilation have contributed to increased IAQ problems. Other contributions to IAQ problems are consequences of other inovations in building fabrics and building materials such as the large diffusion of synthetic materials.

While aiming to reduce energy needs to minimum acceptable levels an other way of conserving energy is trying to diversy the energy sources, looking at more efficient energy systems and energy forms that may be more friendlier to the environment, paying more attention to the climatic conditions, e.g., through the use of solar energy.

The actual situation in most of the southern european countries is characterized by a dramatic growing rate on the use of air conditioning systems in response to better commercial and living conditions. Knowing that air conditioning systems are among the least efficient energetic systems and particularly dependant on electricity, the consideration of the general problem of energy requires the creation of conditions for a more rational use of the cooling systems. That is why passive cooling must become a strategic issue and that IAQ in the warm season should warrant a carefull treatment together with consideration of comfort under transient conditions (for both the heating and the cooling modes).

3. BUILDING PHYSICS AND ENERGY

In general terms, comfort in buildings is mainly related with many environmental parameters such as:

- type of the building and its psycological relevance for the occupants;
- quality of inside spaces: form, dimensions, openings, colours, etc.;
- relation with the outside environment: visual, thermal diode effect, ambient noise, infiltration or ventilation level;
- behaviour of the occupant, including levels of activity and clothing and other behavioural aspects;
- hygiene and health aspects.

So, the comfort issue has very much to do with the building physics, particularly with the building envelope that bounds the indoor and outdoor spaces.

Taking the envelope as a boundary through which heat losses, heat gains and air circulation may take place, the envelope can play one of two main roles: either a) a "definite" barrier between the indoor and the outdoor environments, avoiding losses but also favouring the eventual solar gains; or b) an element that is an integral part of the dialogue of the interior space with the climate, as it is the case of passive solar buildings.

The first type of buildings, is dominated by the internal loads caused by lighting, equipment and occupants. Being well insulated and well sealed, the influence of the outside climate parameters is less important than the internal loads. In this case, energy conservation strategies favour better insulation and reduced levels of ventilation. Consequently, there are greater risks of high levels of concentration of unpleasant contaminants, both gases and particles.

But the second type of buildings is, instead, the so called "envelope-dominated" buildings. In this case, the envelope must allow to play with the geometry of the sun and the solar radiation in order to reduce the needs for conventional forms of energy, using solar radiation for heating and keeping the radiation away to reduce the cooling load. In this case, energy conservation also means insulation but, above all, it means the adoption of the building as a truly "sun trap", collecting and managing the solar energy in winter and rejecting it in summer.

Buildings dominated by internal loads represent the right application for most of what is known and is documented concerning comfort, i.e., steady-state comfort, and what one will call, for the sake of some clarification, the "technological" type of comfort.

A famous architect, Victor Olgyay, all the way back in the 50's, wrote a book called "Designing with the Climate"(3), where he proposed some sort of low energy architecture that was supported by theprectical evidence. Olgyay, and his brother as well, while being Hungarians, were living in the USA and were doing quite well. Their perception and concept of what should be done concerning building design was something much more fundamental than just conserving energy. Being attentive to the trends, in the building industry, Olgyay claimed that a great deal regarding comfort and energy conservation could be done working out better urban planning and architectural solutions. That is why he proposed the bioclimatic chart as a tool to express the climatic conditions of a given place and to evaluate the potentialities of the building design for reaching a certain level of comfort.

Definitely, to assume that the optimum thermal comfort (technological comfort) is not always required or necessary is not a question of descrimination or a minimalist approach. There are many more "nuances" in comfort which will allow for other design options. It appears clear to some authors that what one could call the "technological comfort" may be avoided in some cases and, on the contrary, it seems that there is no reason to recommend as a must, the generalised use of auxilliary equipment for heating and, particularly, for cooling. It appears to be desirable the establishment of a hierarchy of comfort conditions and the definition of the environmental control options accordingly. As an illustration, it is interesting to mention the conclusions of "nordika"(4) concerning the advantages of the decentralization of the systems and, in particular, the need for the systems to allow for the windows to be openable. If the option of the scientific and professional people familiar with buildings dominated by the internal loads is such, how much further can the designers of envelope-oriented buildings go in regions such as those of the southern european belt, avoiding or reducing the use of air conditionning through the "inteligent" use of the envelope? The complexity of the problem in this particular case is evident: not only is it important to avoid heat gains in summer, where the sun is usually abundant, but it is also necessary to enhance heat gains in winter to reduce the needs for auxiliary energy. Moreover, the midseason period is very much adverse to the HVAC designers because while the outdoor temperature is around comfort levels, the solar gains lead quite easily to situations of overheating due to the geometry of the sun rays.

The consideration of the building physics as a pre-condition for smaller energy consumption and, also, a less important IAQ problem has a strong scientific and realistic bacground. Making a plea for a more critical use of the HVAC systems does not mean any type of refusal of the technological development but, well on the contrary, it suggests the need for a wiser use of the available technologies.

Assuming the very first priority for building physics, e.g., urban planing, architecture and construction technologies, the systems are not necessarily to be eliminated. In any case, they shall be more adequate to the real needs, certainly smaller and, hopefully, simpler.

It is offen considerer that natural ventilation should be avoided of the energy consumption associated with it. Everything that has been said suggests that energy consumption with natural ventilation cannot be the unique criteria to decide about the convenience of its use. It must be balanced with other "costs" such as those related with the IAQ.

An unsolved question remains however: how to pass on the information needed by the professionals? Is it available? Or the only solution is to copy what was studied and compiled for other types of climates, needs and cultures? Without forgetting that, even in the latter cases, there have been several changes in the building design strategies, in the last two decades, it seems clear there is a need for a comprehensive study of this issue.

4. COMFORT AS A PREREQUISIT FOR DESIGN

The nature of thermal comfort as a statistical parameter is such that, for all pratical purposes, it is only adequate in nonresidential buildings where conditions must be near the optimum at all times so as to garantee that the largest percentage of occupants may feel comfortable: a minimum of 80% according to ASHRAE (2) and ISO Standards.

Two facts must be taken for granted: the whole framework regarding comfort established by the above mentionned standards; and the progress that has been reached on the assessment and the understanding of IAQ and comfort conditions under such a framework. Nevertheless, this did not avoid the phenomena of the sick building syndrome which seems to lead the treatment of IAQ as an unavoidable problem.

There are, however, many cases of buildings in different regions that may allow for comfortable or almost comfortable conditions by natural means most of the time. What seems to be regrettable is to let the market, every day more globalized, "impose" equipments and systems that are absolutelly necessary in some regions - those where they have been conceived and produced - to other regions where they can be avoided or used in a quite diferent way. The fact that comfort has been better understood and characterized in the more developped regions has to do with the fact that those regions are both the coldest and the richest. There, heating was a necessary condition for survival while cooling resulted mainly from the high level of insulation and sealing of the envelope and of important heat sources inside - cases of hot and humid climate are typical for the use of cooling. The needs for the definition of standards were the natural consequence of a balance between the objectives regarding the indoor environment and economics.

The point to be made here is that, rather than socio-economical reasons, there are comfort and IAQ reasons for differentiating the buildings of different regions as well as there are reasons to differenciate the environmental treatment according to the type of buildings. In residential buildings, the indoor environmental conditions can be allowed to fluctuate. Then, the technological comfort conditions are no longer fully applicable. The same may occur in the case of the envelope-dominated buildings, i.e., buildings where the envelope plays a decisive role in the heating/cooling loads. In this case, as it happens with residential buildings, a large part of the environmental control may be reached by some operating attitudes, either of the users or of some "inteligent systems" on the envelope: shading devices; nocturnal insulation, etc.

An even more complicated situation occurs when those spaces have some probability of being in open contact with outside. In this case, some actions can be taken at the level of the urban planning itself and landscaping as a microclimate control. There appears to be some room for other comfort approaches than the technological one. Authors as N.Baker (5) and X.Berger (6) make a more individual comfort approach, talking of "personnal heating" or "personal cooling" instead of space heating or space cooling. This approach does not respond to the situations where the technological comfort applies, but it will cover a large number of situations such as those of the free-running buildings or those with passive heating and cooling systems. The experiences conducted at the EXPO 92 site in Seville are very good examples of outdoor climatic control approached under this perspective. Many experiences of passive buildings relying on natural ventilation, thermal inertia and free cooling are examples of the same type. Of course, something to be aware of is that, in such cases, IAQ is particularly dependent upon outside air quality since there will be no means, such as filters, to remove the contaminants.

Today, one could dare to try to find a new definition for comfort in parallel with the WHO definition for health: comfort is a state of complete physiological and psycological well-being and not merely the effect of some parameters related with thermodynamics, fluid mechanics and heat and mass transfer, or with the presence or absence of some contaminants. If one could agree on such a definition, comfort would become, as it happens for health, even more of an individual affair. So, it becomes almost impossible to generalize comfort. Therefore, at first, buildings should be designed offering forms of natural control that the ocupant can adjust to obtain the indoor air of his preference.

But one cannot, of course, take into account the temperature, air velocity, moisture levels and chemical and particle effects without ignoring the effects of the behavioural aspects, cultural and personnal habits and activity.

5. CONCLUSIONS

The objectives to be satisfied in buildings have been defined within the framework of the Directive 89/106 (7) and its six essencial requirements. Two of those deal with, respectively, "hygiene, health and environment" and with "energy economy and heat retention". Overcoming the expression "heat retention", which appears in the english version, and clearly demonstrates a bias established by the traditional practice in northern climates, it is clear that the single market of construction materials will impose a broader perspective of energy use in buildings through standards and regulations based on a framework of much more openess to different situations of climate, of culture, of building technologies, etc.

From the discussion, above the following conclusions can be proposed :

- Energy strategies in buildings are influencing the actual IAQ and the comfort situations.

- A large share of buildings could avoid at all or at least have much smaller heating or cooling systems if they were better designed according to climate condition.

- IAQ conditions can be controled by several different ways other than just ventilation rates. Design according to the type of utilization has much to do with it: architectural form, selection of materials, systems option.

- In some buildings there is room to establish a hierarchy of comfort conditions and assure a diversification and a descentralization of energy sources and comfort systems.

- In a free running building, the current concept of thermal comfort may need some adjustments. Comfort, which depends on IAQ and energy parameters, may require much more study and research to deal with less objective conditions and non-steady environmental situations (e.g. person heating or person cooling rather than space heating or space cooling).

- Energy strategies in buildings may reinforce the need for a specific energy conservation strategy that stresses the advantages of designing with the climate. In this case the information on comfort to be passed on to designers must be much better studied and elaborated.

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