ENERGY AND ENVIRONMENT OPTIMIZATION

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ABSTRACT

Incidence of building occupant health and comfort complaints (tight building syndrome) have been linked to energy efficient, mechanically environmentally controlled sealed building technology and systems now characteristic to most office, commercial and public buildings. Prior to the refinement of mechanical control technology and the availability of abundant and inexpensive fuel resources, architectural systems were the primary means of controlling the interior environment. However, mechanical systems do present real advantages to environment control. The proposed design strategy, energy and environment optimization, integrates architecture and mechanical technology for optimum environment control efficiency as required for occupant comfort and efficient energy use. A building design strategy for achieving optimal use of energy resources to provide healthy and comfortable building environments is defined.

INTRODUCTION

Energy and Environment Optimization refers to efficient use of energy resources to achieve acceptable environmental conditions in buildings. Efficient use of energy and provision of comfortable and healthy environmental conditions are basic precepts of contemporary building environmental control theory. However, research has shown that occupant health and comfort problems are a significant issue in contemporary sealed buildings with mechanical heating, ventilating and air conditioning (HVAC) systems. (ASHRAE, 1982; Hicks, 1984; Spengler and Sexton, 1983; Sterling et al, 1983; Sterling et al, 1983a; Sterling and Sterling, 1985) Also, critical evaluation of sealed building environmental control theory and practic has permitted identification of:

1. Key design issues related to environmental quality.

2. A negative relationship between environmental quality and application of energy conservation measures.

3. Inherently inefficient use of energy resources.

These issues serve as the basis for definition of a new approach to building design permitting both energy and environment optimization.

DESIGN AND ENVIRONMENTAL QUALITY

Evaluation of over 200 recorded building illness investigations has indicated that building design is a significant factor related to incidence of health and comfort problems in sealed buildings. (CCAIA, 1984; Sterling, 1977; Sterling and Kobayashi, 1977; Sterling, 1979; Sterling et al, 1983, Sterling and Sterling, 1984) Key design factors may be:

Location of vents and exhausts. Fresh air supply vents can introduce outdoor contaminants into buildings. For example, supply vents located overlooking a busy street or transit stop are often the source of entry for auto and diesel exhaust. Also, poor placement of supply and exhaust vents can prevent exhaust from escaping and instead cause it to be reintroduced directly back into the building air supply.

Location of ventilation diffusers. Both inlet and exhaust diffusers are commonly located in the ceiling. This often creates stratification and short circuiting of supply air at ceiling level, which may result in pockets of dead air and poor circulation at desk height.

Lack of individual control over environmental conditions. All people are not equally comfortable in the same environment. The general practice of controlling environmental conditions over large areas by single controls can contribute to discomfort, stress and minor health problems.

Construction and finishing materials. Synthetic materials used in building construction and maintenance may generate many irritating and sometimes toxic fumes and dusts, including formaldehyde, hydrocarbons, amines, ozone and respirable particulates.

Incorporation of a number of different occupancies within a single building. Many multiplex buildings contain parking garages, access to public transportation systems, restaurants, health clubs and laundry and recreation facilities. These may add substnatial amounts of combustion byproducts including carbon monoxide, oxides of nitrogen, carbon dioxide and diesel exhaust to the indoor environment.

ENVIRONMENTAL QUALITY AND ENERGY CONSERVATION

While design is a significant factor affecting environmental quality, application of energy conservation measures has also led to reduction of occupant health and comfort. While reduced environmental quality as a result of application of energy conservation measures has excaberated environmental quality problems in inadequately designed buildings, energy conservation methods have also limited the ability of well designed buildings to function effectively.

For example, the ASHRAE ventilation standard published in 1973 recommended 25 cubic feet per minute per person of fresh air ventilation in general office areas of air-conditioned office buildings. (ASHRAE, 1977) However, the new ASHRAE Standard, designed for energy conservation and published in 1981, requires only 5 CFM per person of fresh outside air provided smoking is either not allowed or is restricted to designated areas. (ASHRAE, 1981) This amounts to a five-fold reduction of ventilation requirements. The prohibition of smoking in buildings may not entirely compensate for reduced ventilation. Evaluation of American National Institute for Occupational Safety and Health (NIOSH) investigations of buildings with occupant health and comfort problems has indicated that while only 2% of occupant health and comfort problems were linked to environmental tobacco smoke, 48.3% of the problems were related to inadequate ventilation. (Melius et al, 1984)

Thermal environment conditions have also been affected by energy conservation. The current ASHRAE Effective Temperature Scale contained in ASHRAE Standard 55-81 is significantly different from earlier ASHRAE Standards 55-74 and 55-66 (ASHRAE, 1981a,1974, 1966). Standard 55-81 expanded acceptable relative humidity in occupied spaces on a year round basis from the 20-60% range defined by Standard 55-66 to between 20 and 90%, a net increase of 30% relative humidity. Standard 55-81 also expanded the acceptable temperature range from 73-77°F to 67-81°F, effectively tripling the permitted range of temperature fluctuations in an occupied space. The changes incorporated into the New Effective Temperature Scale are not based on new thermal comfort research. In fact, ASHRAE acknowledges that the changes in allowable temperature range are the result of an increasing need to conserve energy as mandated by the United States Government (ASHRAE, 1981b).

The attempt to achieve more energy efficient buildings has also been a major factor in the trend towards reliance on artificial lighting as the primary light source in sealed buildings. It is more energy efficient in sealed buildings to increase as much as possible the ratio of interior volume to exterior wall, as the walls are the major source of heat loss or gain in the building. As a result, the evolutionary process of sealed building design has witnessed a gradual shift from thin rectangularly shaped buildings utilizing natural daylight as light source to square buildings with deep floor plans primarily dependant on artificial lighting for illumination.

Thus, attempts to achieve improved energy efficiency within the terms of reference of the sealed building model of indoor environment control has confronted designers with a dilemma: reduction of energy consumption in sealed buildings has been associated with reduction of environmental quality.

ENERGY EFFICIENCY AND SEALED BUILDINGS

Prior to the development of sealed buildings with environments controlled by mechanical (HVAC) systems, building architecture defined and manipulated environmental conditions within a building. The architectural system was supplemented by mechanical systems as necessity and technological capabilities allowed. Buildings of this type are inherently energy efficient due to reliance on nonenergy consuming methods for primary environmental control.

Sealed buildings with mechanically controlled environments were first proposed by the European architect Corbusier over 50 years ago. To Corbusier building environments which were controlled by mechanical systems represented a means of overcoming the problems associated with architecturally defined indoor environments. Examples include:

1. Locational variation in indoor environment conditions (within the building itself and from place to place).

2. Seasonal variation in indoor environment conditions.

3. Draughts and inconsistent thermal conditions caused by tempering of air after entry to the building.

4. Inability to achieve precisely and at all times use-defined environment conditions.

In addition to improved thermal conditions, and in conjunction with the possibilities offered by new steel and concrete construction technology Corbusier and his contemporaries foresaw the possibility of opening up building interiors to daylight.

However, the fact that the external environment would continue to interact with the building and exert some influence on indoor environment conditions was not considered by these early designers of sealed buildings. A case in point was Corbusiers Cite de Refuge. The Cite de Refuge was an environmental failure because the mechanical system could not counteract the effect of the external environment on the building. (Banham, 1969) The concepts of Corbusier and his fellows achieved effective form only after mechanical control systems designed not only to control the interior environment, but to overcome the effects of the external environment were designed. The inherent energy intensity of sealed buildings as compared to traditional buildings with architecturally modified environments is revealed by the need for a mechanical system to overcome inefficiency of the building enclosure to provide a comfortable interior environment. In sealed buildings energy must be used for environment modification work which had been achieved using nonenergy consuming means in traditional non-sealed buildings.

DISCUSSION

Inadequacies of sealed as well as traditional buildings in the energy efficient provision of acceptable comfort and environmental conditions for human occupancy presents architects and engineers with a dilemma. A design approach which combines the inherent energy efficiency of the architectural model and the ability of the technological model to provide a precisely defined environment independent of external conditions may provide a solution to the dilemma and achieve energy and environment optimization.

Figure 1 is a typical floor plan illustrating a design solution for an office building which combines the positive features of both the architectural and technological design approaches. The building was designed for a site in the downtown core of Vancouver, British Columbia, Canada, where the climate is temperate oceanic with an average temperature range 0-20°C and heavy rainfall.

Ventilation. To avoid the problems associated with a sealed building envelope, this solution incorporates a permeable building envelope allowing air flow in, through and out of the space. Operable air vents or "windows" are used as a means of supplying fresh air. This type of ventilation requires careful design of the floor plan to minimize the interruption of air flow by walls and partitions. The removal of the core from within the building volume eliminates one obstacle to air flow. The design of narrow section floor areas minimizes the possibility of occupant supplied partitioning interrupting air flow patterns. Multi point access to each floor area decreases the liklihood of total partitioning across the air flow path.

Thermal Environmental Control. Particularly in office towers the major function of an air conditioning system is to counteract the tremendous heat generated by lighting and equipment as well as the activity of building occupants. In northern climates, fresh air ventilation alone would probably provide comfortable conditions most of the time. However, for reasonable occupant comfort, air conditioning is often necessary. Heating, cooling and humidity control of the air is handled by units integrated within the window or building envelope itself. The ventilation rate and air temperature is controlled in part by the occupants' use of adjustable louvres, keyed to a central computerized control system. Incorporation of thermal treatment of fresh air at the point at which it penetrates the building envelope eliminates uncomfortable draughts and temperature variations within the space.

Lighting. Limiting the width of the building to a maximum of 12 metres ensures full penetration of daylight from both sides. At night, general illumination is provided by fluorescent lamps, operated manually by occupants. This solution eliminates waste lighting now common due to single circuit control of large blocks of fixtures.

Space Utilization. As much as 25% of the total volume of a typical sealed office building is unoccupied space above the occupied floor for housing of duct work serving the ventilation and air conditioning system. If that duct work were eliminated much of this space could be recovered as usable, rentable floor space. In a typical mechanically serviced office building the floor to floor height is 10 feet. In this architechnological design the floor to floor height is only 8 feet. Therefore, four floors of a typical sealed building becomes five floors of rentable space in the architectural building.

CONCLUSION

The design solution presented is intended to provide another direction of thought towards building environment control system design. The essential point is that architecture is not only the art of embellishment of the exterior facade or the design of spatial experience. The building must also function as a well designed totality which satisfies the aesthetic, economic and environmental requirements of owners, users and occupants. Also, each situation by necessity must be viewed as an individual case - it is not acceptable to assume utilization of one environmental control system or another will be appropriate. Each building must integrate architecture and systems to optimum energy use and environment quality within the terms of reference of the micro climate in which it is built.

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Figure 1: Typical office building floor plan designed for energy and environment optimization