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Assessing Energy Preservative Measures and Substantial Parameters for Optimizing Cooling Performance in Atrium Buildings

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Abstract*: Atrium nowadays is applied extensively by professional designers and owners to bring various benefits such as adequate daylight, circulation spaces and surfaces for landscape applications. One of the most significant problems regarding this popular architectural feature is the space conditioning of atriums which has relatively large volume compared with traditional commercial and institutional spaces. This may lead to high energy consumption, if atriums are fully conditioned unless effective design strategies are implemented. It is often very difficult to achieve high thermal comfort and low energy consumption at same time. The potential for energy conservation through severe control of indoor temperatures strengthen the examination of the applicability of the universal values of comfort temperatures recommended by international comfort standards. The aim of this paper to assess energy conservation measures, which supports to conditions of the thermal environment and has contributed to achieve architectural design features. Systematic investigation of factors for energy conservation via literature review helped to reveal about the design features which have influenced in developing comfortable environment; daylighting, acoustics, natural ventilation and thermal control have been identified as environmental factor in rolling out the architectural features in atriums. The result would help to optimize at initial design stage the controlled environment and would provide valuable feedback to help architects and designers to identify the most energy efficient atrium building type.

Index Terms*: Atrium, Energy Conservation, Daylight, Thermal Environment.

I. INTRODUCTION

An atrium is a great glassed volume located between indoor and outdoor indicates that the environmental conditions like solar radiation, ventilation and heat energy seem intensified, turning them into spaces with a great environmental potential. Atrium has already become a kind of widespread building form in the architecture. Now, the architectural technology has developed constantly, and people bring natural environment into countries and buildings through atriums. The atrium reinforces the relation of the people and nature. It improves environment's quality and people standards.[1] People modify both their behavior and environments to conform to societal expectations of thermal comfort. With the technologies of the modern world, dependence on mechanical systems in the built environment became the norm. Air conditioning technologies have transformed what is regarded as a 'normal' building

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In many different parts of the world that these play a critical role in providing expected comfortable thermal environments in modern buildings. Expectations of a comfortable environment are converging worldwide: hot environments are being cold while cold indoor environments are being heated.[2]

In the atriums of public buildings, the physical environment is determined by architectural features in various ways, therefore, an integrated consideration of the overall physical environment is important.[3] The most fundamental concept of successful atrium design is a good understanding of the complexity of the atrium environment. Atriums are the most complex built environments that most designers will encounter. Atriums are composed of more component parts in more complicated relationships than any other building type. No fundamental component of an atrium should be accepted until its relationship with the whole is understood. For every component and every aspect of every component there will be beneficial aspects and also non-beneficial aspects. There will be "pros" and "cons" associated with every element.[4] The complexity of atrium design does not lend itself to prescriptive standards, but sound life safety principles must be incorporated into every atrium design. Good atrium design will maximize the natural environment to promote energy conservation.

Comfort has become synonymous with the consumption of applied energy. The international comfort standard, ANSI/ASHRAE Standard 55 is used extensively as a reference for comfort levels. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 55 defines thermal comfort as "that state of mind which expresses satisfaction with the thermal environment." It involves the well-being of the occupants in a particular environment for a particular climate about their capacity to adapt to thermal equilibrium, physiological, psychological and behavioral changes.[5] Thermal comfort is often related to the condition of an individual's mind which expresses satisfaction or dissatisfaction with the thermal environment. Man has, for the most part, strived to create a thermally comfortable environment. This is reflected in building traditions around the world - from ancient history to present day. Atria also have potential environmental advantages such as providing natural daylight and natural ventilation for its adjacent spaces.[4]

Atrium is closely linked to the thermal comfort of the occupants, and it is possible to achieve this comfort by reducing the heat gains,

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Thermal control and removing the internal heat and developing Environmental potential through designing and controlling Environmental factors creating potential for energy conservation. Controlling the thermal conditions of the atria are not easy due to numerous characteristics of the space such as walls with large areas, small usage zone ratio, high ceiling and so on [2]. By correct design of atria, the building can be capable of capturing solar energy to reduce the building's energy consumption in addition to creating a comfortable and visually pleasant environment. [6] So worldwide it has become a progressively important need to minimize energy consumption in all energy consuming sectors due to important issues, such as increase in energy demand, energy security, rising energy cost.

II. CONDITIONS OF THERMAL ENVIRONMENT

A healthy and comfortable thermal environment of indoor workspace helps the users to improve their work efficiency by maintaining various comfort related parameters within the desired range.[7] Today, creating a thermally comfortable environment is still one of the most important parameters to be considered when designing public buildings such as an urban entertainment centre. Due to the rapid growth in urban areas and global warming, the issue of thermal comfort conditions have gained great attention.[8] It has also been established over recent years that it is difficult to predict and analyze the internal environments of atria because of the complex nature of their operation and air flows.

The environmental conditions required for comfort are not the same for everyone. Extensive laboratory and field data have been collected that provide the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable. Section 5 of this standard is used to determine the thermal environmental conditions in a space that are necessary to achieve acceptance by a specified percentage of occupants of that space. There are six primary factors that must be addressed when defining conditions for thermal comfort. A number of other, secondary factors affect comfort in some circumstances. The six primary factors are Metabolic rate; Clothing insulation; Air temperature; Radiant temperature; Air speed; Humidity (The *ANSI/ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy)*. But the thermal sensation experienced by occupants in a building space is known to be affected by four primary factors - air temperature, air velocity, humidity and mean radiant temperature (MRT). The calculation of the comfort level in atrium spaces involves two difficulties compared to other spaces. Firstly, solar radiation that can penetrate the atrium skylight has a significant impact influencing thermal comfort and adds to the difficulty of calculating MRT; and secondly, there is strong temperature stratification in the space due to stack effect, which makes it difficult to obtain the air temperature. Focusing on the above two issues, a tool is required for the evaluation of the comfort level in atrium spaces. For the first issue, CFD analysis can be done and MRT calculation method can take solar radiation into account. In order to achieve an environmentally appropriate indoor space for thermal comfort, there is a need to identify the position where an atrium exist and environmental analysis has to be worked out to take advantages through its design and avoid its imperfections. There is requirement of study of relationship between environment conditions and occupant in which several design strategies are to be adopted to fulfill occupant requirements in which environmental factors are to be taken into account with temperature, wind and other climates conditions.

Different studies about atrium thermal performance discuss the importance of energy conservation in designing for new large buildings to reduce energy consumption. Architectural programming establishes the needs and requirements for all of the functions in the building and their relationship to one another. Wise programming maximizes energy savings by placing spaces in the most advantageous position for daylighting, thermal control, and solar integration. Initial decisions, such as the building's location, general massing, and configuration profoundly affect the building's environmental impact and energy performance.[8]

III. DESIGN PARAMETERS INFLUENCING THERMAL ENVIRONMENT OF ATRIUM

Typical atrium configurations can be totally surrounded by building elements or partially enclosed. They maybe top lit, side lit or a combination of both. The configuration of the atrium will dictate many of the fundamentals of atrium the components. The first consideration of atrium design is an acknowledgement of the necessity of fire and smoke management. Building configuration is the most significant factor in smoke management and thus must be fundamental to the design.[9] The design parameters of an atrium include glazing type, ventilation strategies, shading configuration, geometry, etc. and their impacts to building energy performance. The interior environment of an atrium is affected by numerous design parameters such as orientation; envelope properties; heating, ventilation, and air conditioning (HVAC) system; attributes of adjacent spaces; atrium shape and type; roof aperture; transmittance of the roof; and glazing area. It requires a systematic work to improve an atrium's interior environment.[10]. The interior environment of an atrium is affected by numerous design parameters such as orientation; envelope properties; heating, ventilation, and air conditioning (HVAC) system; attributes of adjacent spaces; atrium shape and type; roof aperture; transmittance of the roof; and glazing area. With an increased awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly attractive method for reducing energy use and cost and for providing acceptable indoor environmental quality and maintaining a healthy, comfortable, and productive indoor climate rather than the more prevailing approach of using mechanical ventilation. In favorable climates and buildings types, natural ventilation can be used as an alternative to air-conditioning plants, saving 10%–30% of total energy consumption. [4]

It requires a systematic work to improve daylight enhancing the atrium's interior environment.

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The reason why the design parameters of an atrium affect its energy performance lies on their impact on the atrium interior environment. Consequently, the interior environment of an atrium is a significant matter that should be examined considering thermal environment, daylighting, ventilation, and air quality.

IV. GENERIC FORM OF ATRIUM AND DAYLIGHTING

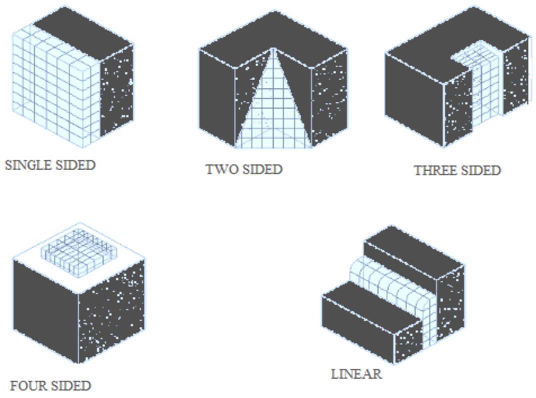

Fig.1 Forms of Atrium

Fig. 1 shows different shapes of Atrium which can be developed to numerous architectural accounts but the basic configurations remain noticeable. Which configuration is utilized by an individual designer is a function of (among other issues) personal taste, life safety issue.

V. ENERGY CONSERVATION MEASURES

To achieve their energy efficiency benefits, passive solutions for ventilation, heating and cooling usually need to be applied in a controlled manner. In particular, the controlled use of daylighting, natural ventilation and passive heating and cooling can create a low energy building with reduced environmental impacts, whilst still achieving comfortable conditions for user. A key goal to achieve high performance in terms of both energy conservation and the quality of the user's experience should be a collaborative design strategy which lends itself to better use of the energy required to operate the building. Remarkable issues which creates discomfort in thermal environment are Overheating, Stratification Solar Heat Gain, Glare, and Ventilation Control

There are many potential preservative measures for energy efficient atrium buildings. The most important are as follows:

a) Shield or barrier
b) Optimum orientation and configuration of the atrium building
c) Efficient design and operation of HVAC system
d) Stratified cooling,
e) Passive cooling
f) Passive heating, and
g) Daylighting

A. Atrium as a Shield or Barrier

Atrium is a transition space between the indoor and outdoor environments and could be helpful for energy savings. Therefore use of atrium as a buffer zone, can reduce the transfer of heat through walls functioning as an intermediate space. It can also be noticed that the heat transfer intermediate walls of spaces facing an atrium may be considerably reduced even with the high U-values of intermediate walls. This could be achieved by maintaining the temperature of the atrium as the stack effect is proper way of replacement of air temperature due to temperature differences in internal and external part of Atrium building. The shielding effect of atriums is beneficial whether the occupied spaces are being heated or cooled, because it reduces heat gain and heat loss during summer and winter respectively. Placement of Atrium also protect walls of the buildings facing them from direct solar radiation, rain and infiltration caused by wind.

B. Configuration of the Atrium building and Ideal Orientation of Fenestration System

Configuration of atriums is another important design factor for energy preservation, whether unconditioned, partially conditioned or fully conditioned. For attached and linear atrium buildings with equal area, the attached atrium will be more energy-conserving, if the atrium is unconditioned, while the linear atrium will be more energy-conserving if the atrium is partially of fully conditioned, because of the large proportion of exterior glazed surfaces exposed to outdoors in attached atriums. Similarly, core-type atriums will be more suitable if full conditioning is required, because less glazed surface is exposed to outdoors than in envelope type.

One of the most important design considerations for energy conservation in atrium spaces is the orientation of fenestration of Atrium. It is analyzed that low-angle solar radiation is difficult to control therefore it is better to avoid east- or west fenestrations; north- or south-oriented fenestration system in atriums are preferable. About building in a warm climate, a glazed wall facing north is beneficial to avoid solar gain, while preserving a glare-free view vice-versa in cool climates, a south-faced fenestration in atrium is the most useful, mainly designed to keep out high-angled summer solar radiation whereas admitting low-angled winter solar radiation for passive solar heating.

C. Efficient Design and Operation of HVAC System

Studies have shown that it is still possible to build energy efficient atrium buildings through more efficient operation and design of HVAC systems by proper implementation of efficient operation techniques such as thermostatic control (night set-back in heating mode and night set-up in cooling mode, increase in dead band) and destratification help to reduce energy consumption in atrium buildings. Still, efficient design of HVAC system with variable air volume system instead of constant air volume system and heat pump type system instead of electrical heating system reduces energy consumption. Incorporation of intelligent building automation system is another practicable option for energy conservation, which might help to reduce peak load demand.

D. Key Preservative Measures

1. Air Stratification in Atrium

Air stratification results from the impact of buoyancy and the stack effect.

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The temperature of air throughout a complete space will be maintained close to the same level. Providing air mixing cooling systems (as opposed to displacement ventilation systems), cool supply air will usually be spread from the top level and return air will be collected either at the bottom or top level. If the occupied zone is only up to a few meters above floor level, not throughout the entire volume. In such cases, a stratified cooling system could be used successfully. Proper use of thermally stratified cooling system may be especially helpful in dropping some potential thermal loads by separating them in the upper zone, thus reducing the initial and operating costs of the equipment.

2. Passive Cooling

Mostly atrium buildings have extensive use during daytime, they may necessitate cooling for the common of twelve-monthly working hours .Passive cooling techniques that can be used in atriums such as Shading of Heat gain part; Providing Thermal mass to envelope; Cooling through Radiation; Cooling through Convection

Solar shading devices may reduce solar heat gain in summer. Detail calculation must be carried out for each case before utilizing such technique such as providing vertical exterior shading that can be most effective on the east and west for lower sun angles, horizontal shading on the south for higher sun angles. One way can be a moveable external shading, which provides desired effect in both summer and winter.

Thermal mass is the ability of a material to absorb and store heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. Thermal mass of the building can support in decreasing the temperature of the building at and eventually absorb the heat produced in building throughout the daytime. This is suitable for the places where night temperature drop below 20 °C and diurnal temperature swing is 10 °C. At night, external cool air flush the heat absorbed in an atrium during daytime. During the daytime cool air from floor may be supplied from the bottom of the atrium.

In radiative cooling under clear sky, heat get transfer most efficiently by means of radiation from a warm atrium to the cooler sky. But the possibilities for radiative cooling decreases as the sky becomes cloudy or humid. The cold night sky and the polar sky during mild summer days can serve as a heat sink for the radiative cooling of a building. Convective cooling (natural ventilation). Natural ventilation driven by stack effect might be capable of maintaining comfort conditions in regions with summers and effectively produce good results with the increase in Sectional Aspect Ratio (SAR) and decrease in Plan Aspect Ratio (PAR. Noticeable conditions for natural ventilation is that the temperature of outdoor air should be less than indoor air.

3. Passive Heating; a Conservation Measure

The probable condition for utilization of direct solar radiation depends upon the proximity to taller buildings and orientation of the building, which determine the availability of direct solar radiation. The difficulties related with passive heating are over-heating, radiation loss. Temperatures within atriums may rise far above comfort levels during sunny days but during overcast days and nights, atrium in cold regions may experience radiative heat loss as well as downward movement of air.

On the other part in winter, the possibilities to store large amounts of heat inside atriums increases with the increase in glazed materials as it is a property of glazed materials to admit solar radiation with short wavelengths and trap radiation with long wavelengths. Large glazed areas help to warm an atrium by admitting large amounts of solar radiation, and massive concrete walls and floors stores the solar heat. These heat is stored in high thermal mass materials could be recirculated into atriums in order to avoid condensation during cold nights or can be directed to other spaces requiring heat during the day

4. Use of Day lighting As Energy Preservation

We need light to see! Daylight penetration into buildings has been a design consideration for as long as buildings have been built.[11]

Fig. 2 Daylight Entering Building

Using daylight as part of an integrated and controlled lighting strategy is a key component of a sustainable, environmental approach to architectural design. Fig. 2 is a top lit Atrium, potentially a major source of daylight for deep plan buildings and offers other environmental benefits in terms of solar gain, reduced energy losses and natural ventilation. [12]

Daylight as it pertains to atriums is a basic element of the design. The light within the atrium as well as the light transmitted to the adjoining occupied space needs to be considered. The light coming into the atrium is impacted by several factors: The average brightness of the local sky is a factor. This will affect the amount and type of glazing used for the exterior skin. Sufficient openings should be provided for the amount of light expected at the bottom of the atrium space. Additionally, the type of glazing, whether transparent or translucent will impact the amount and quality of natural light admitted to the atrium.[13] Daylight is constantly variable and often unpredictable. Daylight approaching the floor is the light of the sun (sunlight), diffused light by the earth's atmosphere and reflected light from the ground or other surfaces.

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It is necessary to judge about the quantity and quality of light emerging by the different sources at particular location. It is found that daylight performance of an atrium is complex, and depends on its orientation and geometry, the surface finishes of its wall and floor, and the shape of its roof and fenestration system. The study tells, the proportions of the atrium determine the amount of direct daylight reaching the floor - wide, shallow, square atria perform better in this respect than do deep, narrow, rectangular ones.

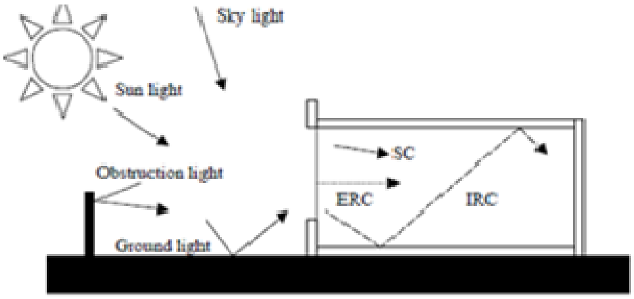

Fig. 3 Daylight Penetration Into the Building

Fig. 3 is a diagrammatic representation of the light source penetrating from side lit opening signifying the quantity of daylight obtained within a space. Taking white walls as the reference condition, 50% glazing will halve the IRC and curtain-walling (100% glazing) reduce it by two thirds. The upper walls are the most critical in reflecting incoming light down into the atrium, so that it is best to limit windows in this area.[14]

Windows and skylights are the main components that admit daylight (sunlight and skylight) into the building. Parameters like orientation, geometry and space planning of the spaces to be lighted; the dimensions and orientation of the openings through which daylight will pass; the location and surface properties of any internal partitions which may reflect and distribute the daylight.; the location, form and dimensions of any shading devices which will provide protection from too much light and glare.; the light and thermal characteristics of the glazing materials used clearly state the quantity of daylight obtained within a space, thus improving performance of Atrium.

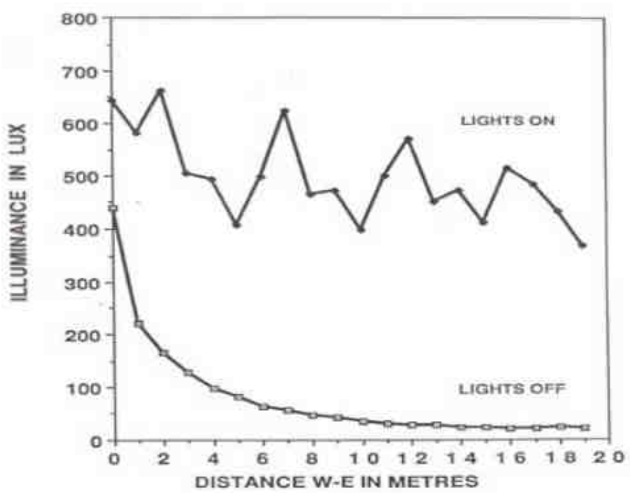

Fig. 4 Illuminance with and Without Lights

Fig. 4 is a graphical way to signify potential of atrium space with and without light.Dependency on artificial light for enviromental comfort is a lead to global energy consumption. We are aware of the fact that total global primary energy consumption in 2006 was 472 quadrillion (1015) British Thermal Units (BTU) (1 BTU = 1055.1 joules), which is equivalent to 138330 TWh (EIA 2006). [15]Therefore, daylighting is one of the potential areas to reduce building energy use as well as peak energy demand. The daylighting potential of atriums depends upon their ability to admit daylight to adjacent spaces. There is a wide range of glazing materials available to control solar transmission, and U-values. One disadvantage is that is affects the whole year. Dark colors might give a continuous dull impression. Large glazed area in atriums will help to admit more daylight into the center of a building and allow reduction in the use of artificial lighting. Artificial lighting not only consumes electrical energy but also produces a large amount of heat, which eventually increases cooling loads in hot weather, but may decrease heating loads in winter. For each case, it is necessary to determine the optimal balance between daylighting, cooling and heating loads in a way that ultimately reduces total annual energy use.

VI. CONCLUSION

It is concluded that atrium is attractive place under all weather conditions from life-threatening external weather. Acknowledging these highly glazed spaces of buildings as a sign of advanced technology, can better become one of the green designs with proper daylight and thermal environment further, proving to be an intelligent means for energy saving. Currently the concept of energy efficient Green buildings has fascinated all the researchers and Architects to switch over from the present practice of mechanical cooling to ancient methods of passive cooling methods, proficiently in new way. Balancing the heat gain and daylight for the interior space atrium design are complex. But in the context of energy saving, along with the comfort condition of atrium, it is advisable to assort various cooling methods in respect to choice of buildings and the associated materials, has to be worked out with one solution.

Therefore the paper is written in a notion of providing useful information right from the concept of passive cooling and the detailed review provided under each category for the building design. Atrium can be acted as a solar collector and distributor, when spaces placed round it. It is also able to give shade and store heat with appropriate orientations and configurations. Atrium contributes to passive heating and is useful in an overall ventilation and cooling strategy, and always makes daylight more available to the spaces that surround it. Properly designed atria have the potential to significantly reduce building energy consumption. In contrast, a poorly designed atrium can result in uncomfortable daytime temperatures and additional air conditioning loads. By allowing daylight into the building, an atrium can reduce the amount of electricity used; however, if excessive daylight is permitted then glare can be a significant issue. Moreover, Natural ventilation in an atrium allows for removal of excess heat and can replace or supplement mechanical systems. the designer needs to understand both positive and negatives aspects of the components incorporated in design to create comfortable environment in atrium.

It is expected from engineers and architects to evolve with multiple concepts for specific site resulting out an energy efficient design. A new workouts regarding Green building concept unquestionably suits for one place but not may not be suitable for another, if the climatic conditions are different. Hence, extraordinary movements of modernizations for climatic zones like hot and dry, warm and humid, cold and sunny, cold and dry, composite conditions etc. are challenging opportunities to develop an integrated approach to energy use and savings, including the determination of the physical form and characteristics of the building.

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