COVERING ATRIUM SPACES AMONG BUILDINGS IN THE CENTER OF MOSCOW

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Abstract

Central part of Moscow city mostly consists of 4-6 story office buildings, where covering spaces between them can be applied and where there is a growth of interest in urban design. There are two types of office buildings: old buildings (built in 18-19 century), which were refurbished from private houses to offices and new buildings that were designed from the beginning for office spaces. New buildings were mostly designed with some public spaces on the ground level, while working environment in refurbished buildings is not so comfortable and does not provide any mixed-use spaces.

Covering space between refurbished old buildings suggest to improve the environment conditions and comfort of the users. Also, covering influences the environment inside buildings and helps to protect the façade from brittle fractures. Sheltered space between buildings is a great amenity in itself, creating a type of space available in most cities – an all-weather public gathering space (Saxon, 1987). Last year Moscow government approved the programmer of pedestrianisation many streets in the city center, so there is a demand in designing these new spaces.

This research paper aims to study the typologies of covered spaces going through daylight, ventilation, passive cooling and heating strategies, reducing costs and increasing comfort. The research focuses on how to make these spaces more comfortable both for the workers and pedestrians without compromising adjacent buildings.

Keywords: atrium, office building, covered space, transitional space

ИСПОЛЬЗОВАНИЕ УЛИЦ ЦЕНТРА МОСКВЫ КАК ПЕРЕКРЫТЫЕ ПЕШЕХОДНЫЕ ЗОНЫ

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Аннотация

Центр Москвы в основном состоит из 4-6 этажных офисных зданий, пространство между которыми может быть перекрыто. Старые доходные дома реконструированы под офисы, где первые этажи занимают магазины и другие общественные пространства. Перекрыв пешеходную зону между зданиями, можно сделать не только комфортным пребывание людей там, предоставив им общественное место круглогодичного использования, но и повлиять на среду внутри здания.

В данной статье рассматриваются различные виды перекрытых атриумов, их вентиляция, дневное освещение, отопление и кондиционирование, а также влияние на энергетические затраты прилегающих зданий.

В холодное время года перекрытый атриум используется как аккумулятор солнечного тепла, снижая затраты на отопление зданий. Летом оболочка образует тень, что положительно влияет на комфорт пешеходов и так же снижает потребность в кондиционировании. Для достижения наилучшего результата могут быть использованы: сплошная естественная вентиляция, вентиляция через крышу атриума, солнцезащитные

жалюзи. Кроме того, фасады зданий становятся менее подвержены влиянию окружающей среды, что помогает сохранить их исторические фасады. Такое место становится «гостиной» прилегающих зданий, предоставляя комфортную среду как в холодное, так и в теплое время года.

Ключевые слова: атриум, оболочка, офисные здания, публичное пространство

CLIMATE CHARACTERISTICS

Design of covered spaces required an understanding of the local environment to achieve desirable conditions. Moscow is situated in a continental climate zone Latitude 55^{o}N, where summers are humid and warm-to-hot, while winters are cold to very cold (Fig. 1). Therefore the design strategies for the summer and for the winter in this region would be quite different and often even contradicting. The combination of warm temperature and high humidity in summer leads to use sufficient natural ventilation as the major strategy for minimizing thermal stress in countries, which cannot afford mass use of air conditioning (Givoni, 1997).

Table 1. Amount of the days with precipitations for Moscow. Source: VVC Weather Station

Precipitation type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Snow	20	16	11	1	0	0	0	0	0	3	10	18	79
Mixed	5	4	6	5	1	0	0	0	1	4	8	7	41
Rain	1	1	3	10	12	14	14	14	15	12	6	1	103

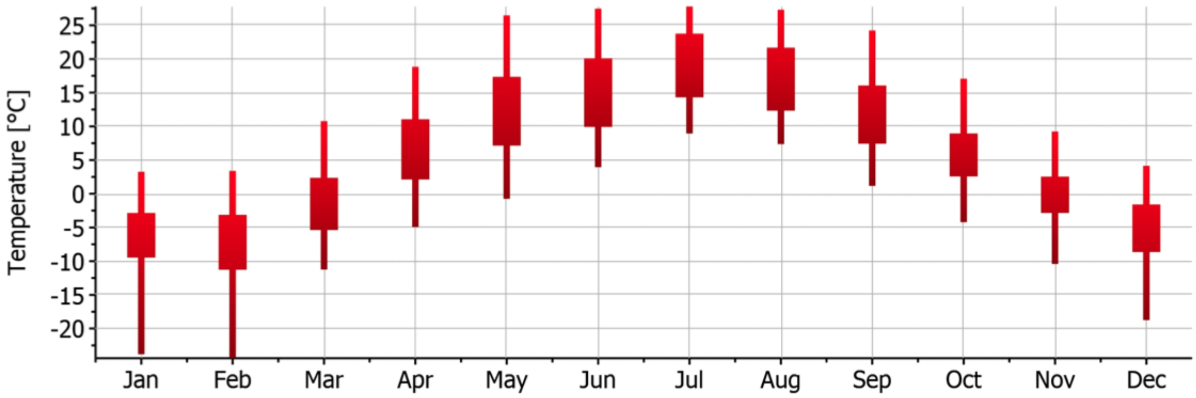

Figure 1. Monthly temperature data. Source: Meteonorm 7

Midseason and summer can be characterised as a rainfall period (Table 1), so natural ventilation through open windows should be provided while rain penetration into the building is not permitted. Winter design objectives are opposite – design strategies should minimize wind penetration into the building, because cold discomfort is strongly affected by the wind speed. Mainly very cold winter days (below -15^{o}C) are sunny with absolutely clear sky that makes solar energy to be a significant source of heating energy. Also, to reduce space heating requirements Saxon (1987) suggests high density in the retail and commercial sectors of the city that implies more intensive use of the land. This proves the need in covering spaces between buildings with their further development.

Modern insulation materials in combination with solar strategies can greatly reduce heating energy consumption even in cold winters. According to Givoni (1997) materials with heatretention properties are less effective in modifying indoor temperatures when comfort in summer is considered. Consequently, comfort issues in hot periods may have higher priority from the design aspect.

PEOPLE: NEEDS AND COMFORT

Climate specifications of Moscow region lead to accommodate different uses in the same building or complex in order to enable people to work and shop in the same place where they abide. People need more comfortable outdoor conditions throughout the year. Covering spaces between buildings provides protection from the wind and the snow to the pedestrians, and thus greatly increase the comfort of the customers, especially in winter, that may attract more customers to the covered street or courtyard, enhancing the profitability of the stores and offices located there (Givoni, 1997). In terms of people`s needs, covered spaces (hereinafter “atrium”) provide common area to organizations located nearby and making them more cohesive.

Especially in Moscow, when outdoor environmental conditions are not comfortable through many periods in a year, designing of positive indoor space such as atrium can be a significant motivating factor for its creating (Bednar, 1986). It is assumed that covered space between office buildings is occupied during the whole day, because main users of these spaces are people, who work there. Nowadays in Moscow there is a demand in 24 hours working spaces, so atriums should provide possibility to be constantly used all year round and can be designed as semipublic or public space. Classically, the cover space in a courtyard in a building was a private space for exclusive use, such as at the Reform Club in London, but this is related to a new building with an atrium. Privatization of the space between existing buildings today is impossible in Moscow. Covering space means to bring new functional capabilities to the area. It can be designed as a space for temporary exhibitions, for making some events, as a gallery with a garden or converting ground floor into shopping area with cafes and restaurants, that allows people to work and shop in the same building complex and attracts pedestrians to get inside.

One of the main aims of designing an atrium in Moscow is to take into account climate features: hot summers and cold winters. According to Givoni (1997), personal protection from cold is more easily to achieve than personal protection from excessive heat. People`s clo level is sharply varies during a year. In summer the value is about 0.3, in midseason around 1.7, while in winter it can reach 3.0. Taking into consideration, that atriums are occupied both by pedestrians and workers, the comfort temperature should consider both cases. Therefore, using Comfort Calculator (ISO 7730-1993) and basing on Meteonorm weather data and changes of people’s clo level through the year, it was calculated, that in winter when outside temperature is -15^{o}C comfort limit should not be below 18^{o}C, while in summer with +25^{o}C the maximum inside temperature can be around +24^{o}C. Climate Consultant 5.4 calculations (Fig. 2), made for pedestrians and based on ASHRAE Standard 55-2004, also prove it, where the minimum comfort limit is 10^{o}C. In winter set of a minimum inside temperature depends on the functional purpose of the atrium. In cold period it can be used just as a buffer space, reducing additional heating demands of the space.

TYPOLOGIES OF COVERED SPACES

A result of covering space between buildings can be closed or semi-closed atrium, which is more difficult to control in Moscow climate. Therefore this research paper focuses on closed spaces that can be any shape in plan, where the only source of daylight and view is the skylight and glazed side walls, which establish a visual relationship between the street and the indoor space. Also, it is possible to cover small courtyards surrounded by buildings, to transform it into the atrium. This new indoor space can be subdivided on with and without refurbishing the building. The minimum refurbishment imply to modify ground floor into retail spaces and changing windows from double to normal glazing if it is required. As it was mentioned before, most of the office buildings in the city centre are under preservation, and covering them helps to save the façade. Bednar (1986) wrote:

"Atria can be used to give historical preservation projects new spacial identity, complementing the visual identity of the building`s original facades"

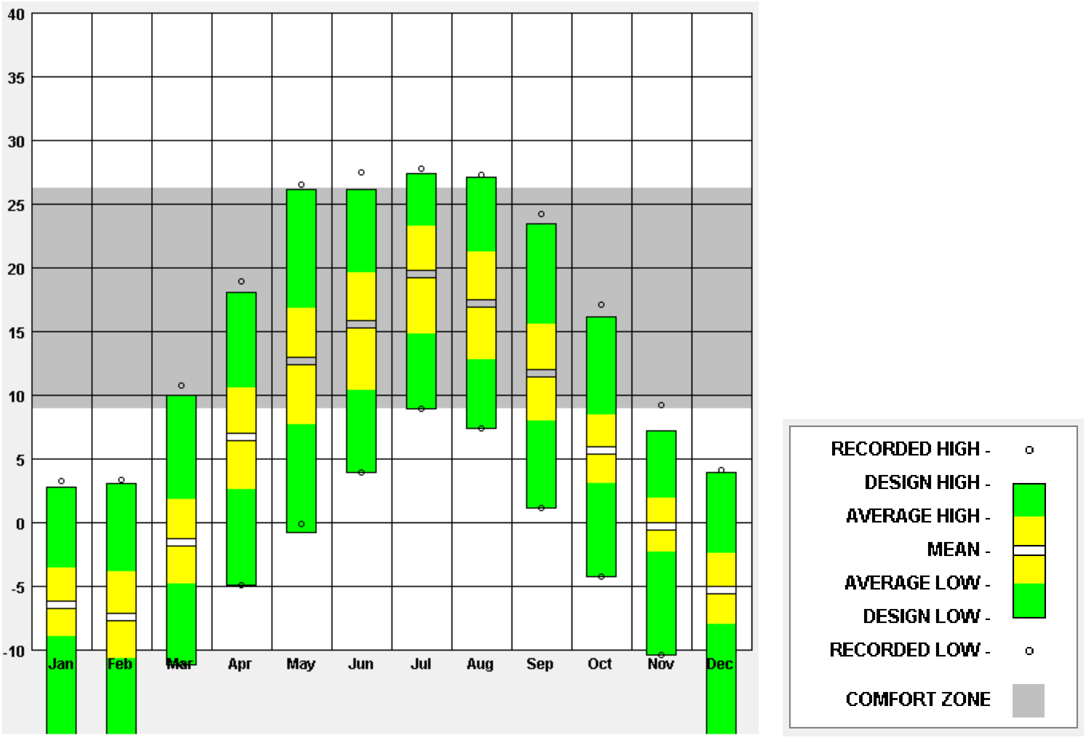

Figure 2. Comfort temperature range. Source: Climate Consultant 5.4

Figure 3 shows one of the examples of covered space connected to the old building, where the large sky-lit court has been created to add more galleries for the museum with leaving the historical façade visible.

Figure 3. Charles Englehard Court, Metropolitan Museum. Source: Saxon, 1987

SUSTAINABLE DESIGN STRATEGIES
DAYLIGHT AND SOLAR CONTROL

One of the strongest design agenda of the atrium aimed to energy reduction and conservation in buildings is in the use of daylight. For Moscow often overcast climate daylighting expectations should be based on the cloudy sky. Then the ideal atrium would be largely top-lit with a clear glazed roof to reach the maximum transmission of the light, while diffuse light would also enter the atrium. Based on climate specificity, use of adaptable louvers can be the right solution to prevent direct sun in summer and minimise obstruction in winter. In TVA building in Chattanooga were used small external shade-vanes, which are controlled by sun-following photocells. The surface of these vanes is mirrored on one side and white on the other, that maximizes the amount of daylight through the whole year, and also work as a night shutter (Fig. 4).

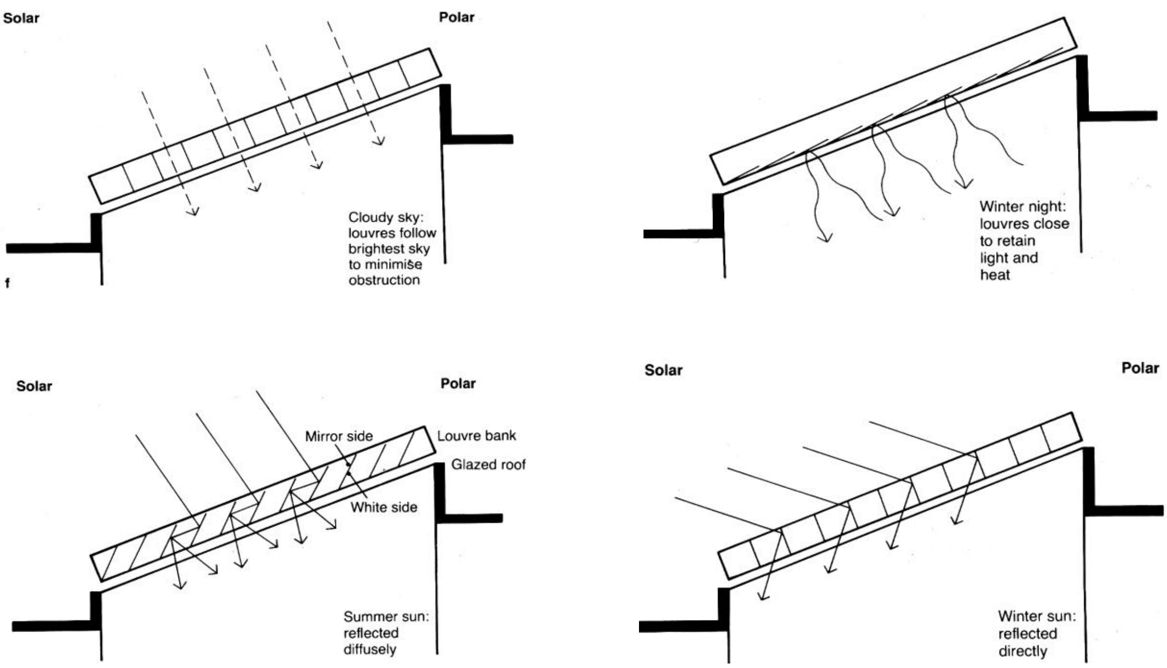

Figure 4: Active shaded rooflight for TVA Headquarters, Chattanooga. Source: Saxon, 1987

Distribution of light within the atrium is depending on how reflective the walls are, but this research paper is focused on covering space between existing buildings where there are no options to change the façade. The only thing that can help the light diffusion is a floor coating. White glossy surface reflects light that makes ground level brighter. It helps to decrease the use of artificial light and as a result saves direct energy consumptions and reduces cooling loads due to internal heat gains.

CREATION A MICROCLIMATE: HEATING, COOLING AND VENTILATION

Atrium leads to two natural things: the greenhouse and stack effect that can work for and against the comfort. The reason of the greenhouse effect is short-wave heat radiation from the sun, which cannot pass back through the glass and as a result leads to positive effect in winter and negative in summer. Heating is required for Moscow climate, because the temperature in atrium itself generally can be at least just 5 degrees warmer than outdoor temperature, which is not enough for very cold periods. The indoor temperature mainly depends on the atrium`s volume, heat losses of buildings, orientation and occupancy. Thermal storage capacity will slow the build-up of heat when the sun is shining and spread the warm during cloudy periods. Since most of the office buildings in the city centre are made from bricks, their thermal mass structure assists in minimizing temperature differential during the day.

Moscow temperatures in cold period force to spend energy on heating demand. Most glazed covered areas function as direct gain spaces, storing heat due to the greenhouse effect. Then warm air from the top part of the atrium can be recirculated to the ground level to provide free heating exchange. Also, surrounding buildings, depending on its internal gains and the thermal separation between it and the atrium, can increase the temperature in the atrium. Air from the occupied offices of the building can be direct to heat the atrium or, depending of the heating system of the building, air supplied for the offices can be passed through the atrium for preheating to reduce energy consumptions. To minimize energy demand on heating it is useful to install in the ventilation system an air-to-air heat exchanger, which extracts heat from the exhausted air and warm the intake air. Figures 5 and 6 show ventilation strategies for a buffer atrium. In winter it is slightly warmed by exhausting air into it after heat recovery, while in summer it is cooled by movement of exhaust air plus any supplementary natural ventilation (Saxon, 1987).

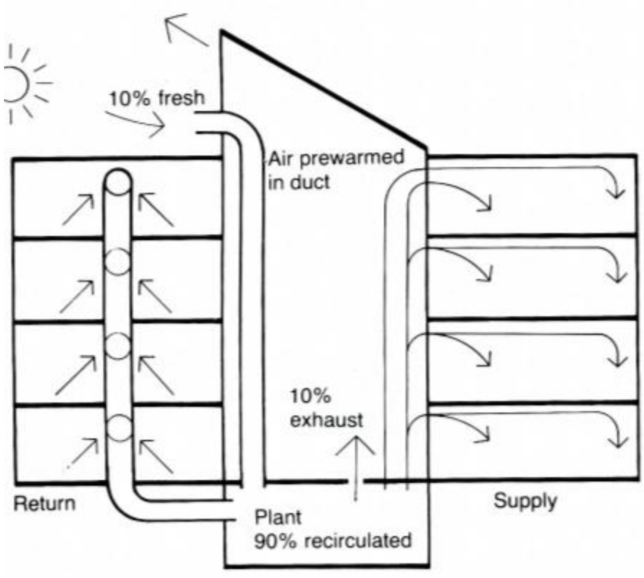

Figure 5. The warming atrium, winter case. Source: Saxon, 1987

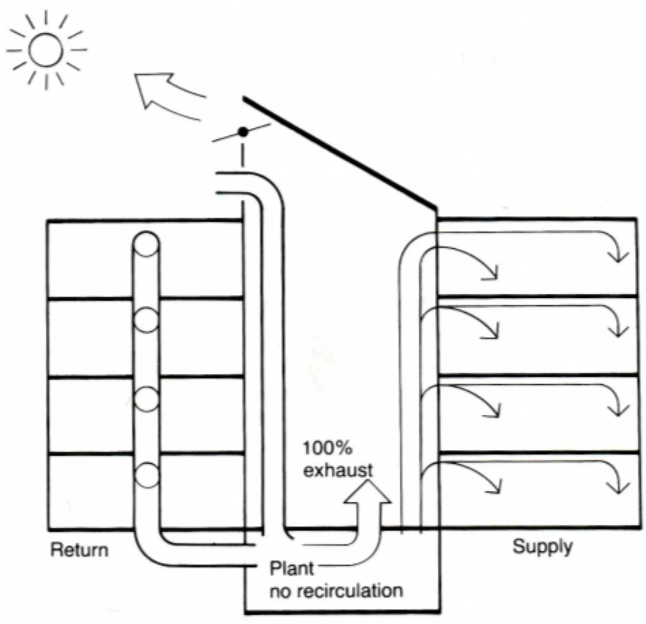

Figure 6. The warming atrium, summer case. Source: Saxon, 1987

Summer temperatures indicate that apart from solar control strategies, which aimed at blocking direct solar rays, there is a need in cooling the space. Bednar (1986) classified cooling strategies on control of solar heat gain use of thermal mass, radiative cooling, and convective cooling.

The thermal mass of a building can be used in a cooling strategies by reducing indoor temperature at night and using cooled night air at daytime. Good ventilation allows cool night air to go through the building, removing hot air and cooling the structure. This is particularly effective in Moscow climate, where there is a big difference in day and night temperatures.

Radiative cooling technique represent cold night sky serves as a heat sink for the building, where the horizontal surfaces faced the sky can attain great amount of heat losses (Fig. 7).

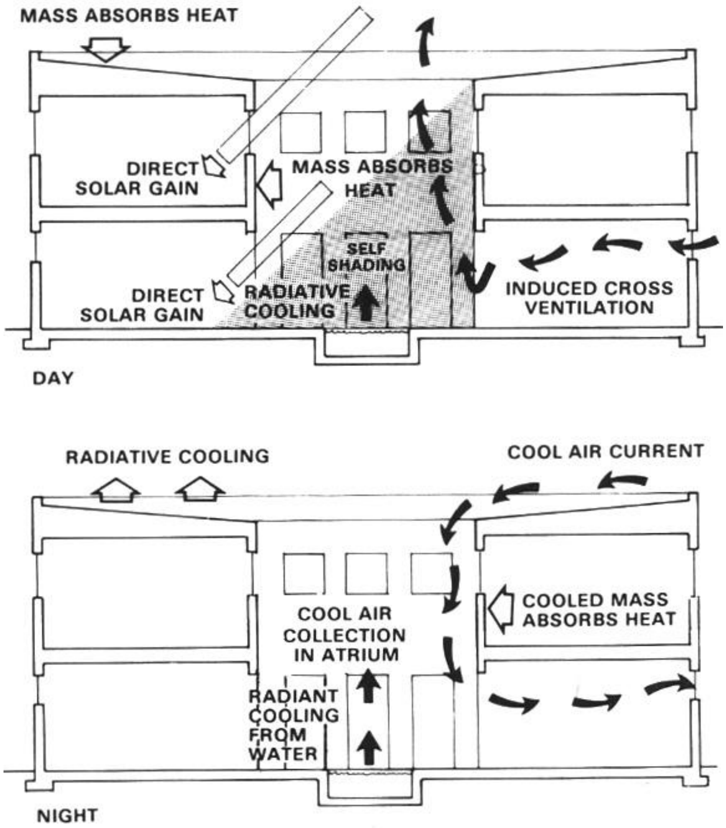

Figure 7. Natural energy flows in an atrium house. Source: Bednar, 1986

Convective cooling is based on the stack effect and considered to be the most useful technique in passive cooling. Saxon (1987) described the stack effect as the result of the action of pressure differences with altitude. Hot air is thrown out from the top of the atrium creating a convective airflow. Using solar chimney effect with appropriate air inlets and outlets can improve the vertical stack effect.

Covering space also reduces energy consumptions of the buildings. Calculations of different glazing types in ELA atrium building in Trondheim, Norway showed double low-e glazing as a best solution (Fig. 8). Figure 9 indicates total energy consumption for a building with an atrium heated to 18^{o}C, a free floating atrium (Rome), and a building with no atrium (Washington); the building is both heated and cooled (Dallas). Best results shows the free-running building in Rome, what proves the positive impact on the excising buildings.

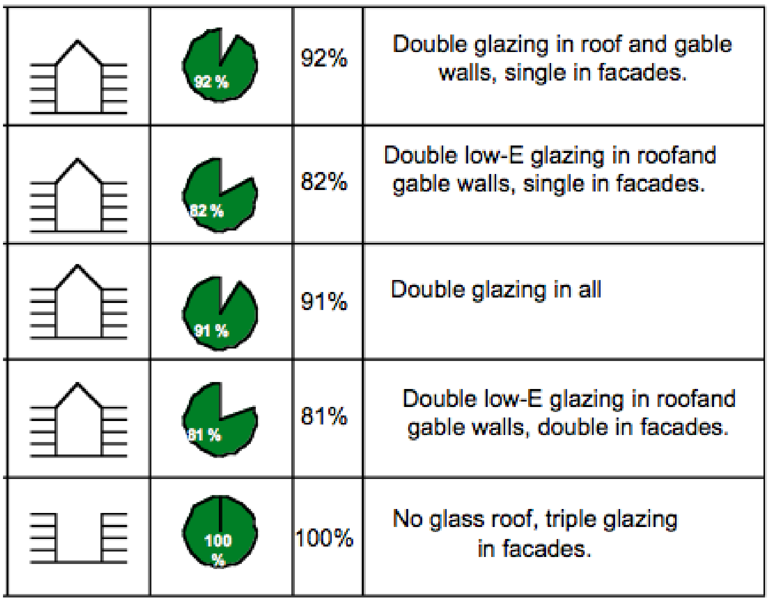

Figure 8. Energy consumption for heating the ELA building for different glazing alternatives (Source: www-cenerg.ensmp.fr/ease/sunspace_atria.pdf)

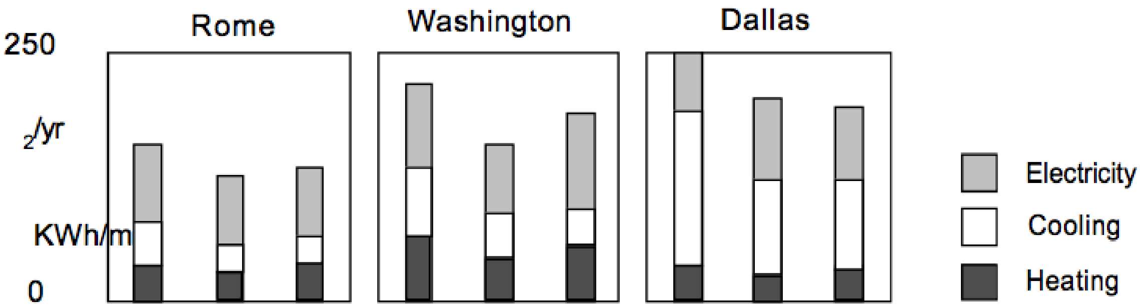

Figure 9. Energy consumptions of different atriums
(Source: http://www.cenerg.ensmp.fr/ease/sunspace_atria.pdf)

SPACE DESIGN DEVELOPMENT

Designing small gardens and atriums goes together in the designer`s mind for many centuries, becoming a traditional elements in covered spaces. Water and plants not only create a visual comfort to the occupants, but also play a huge role in indoor microclimate. Pool helps to reflect daylight and in summer works as natural radiant cooling, small fountains provide visual sparkling (Hyatt Regency Dallas), while larger are used to improve acoustic sounds (Hyatt Regency Atlanta). In winter when outside temperature below zero degrees water does not bring positive visual enjoyment, therefore it is better to pour water to have a dry decorative pond filled with gravel and stones, which can also work as a thermal mass.

Small trees and other plants can be installed in the atrium, but they should not block daylight and create shading.

All these design proposals can improve the acoustic performance of the covered space, which volume causes by nature to be reverberant.

BUILDING PRECEDENTS

Three examples of atriums in buildings were chosen: two of them represent refurbishment of the spaces between buildings (A, B) and one is an example of new office building with atrium space (C).

A. Erie County Community College, Buffalo, New York

First, the building was built in 1900 as a post office with one-storey skylit court used as a mail sorting room. Then, in 1982 Cannon Design architects refurbished it into the college. They designed a new glazing cover and created a four-storey atrium (Fig. 10), placed offices with galleries on each level facing the atrium while classrooms were located it the perimeter of the building. Architects used to install new splinkler system into the new columns inside the atrium and bronze splinklers on the historical walls. The new skylight was made of double-wall fiberglass panels (0.24 U-value); also double glazing was installed in all external walls. Architects removed steam radiators and designed new the closed-loop heat pump system, which transfer the heat in room spaces when it is needed. Heating exchange between top of the atrium and ground floor and heavy brick mass of the structure also helped in creating comfort conditions.

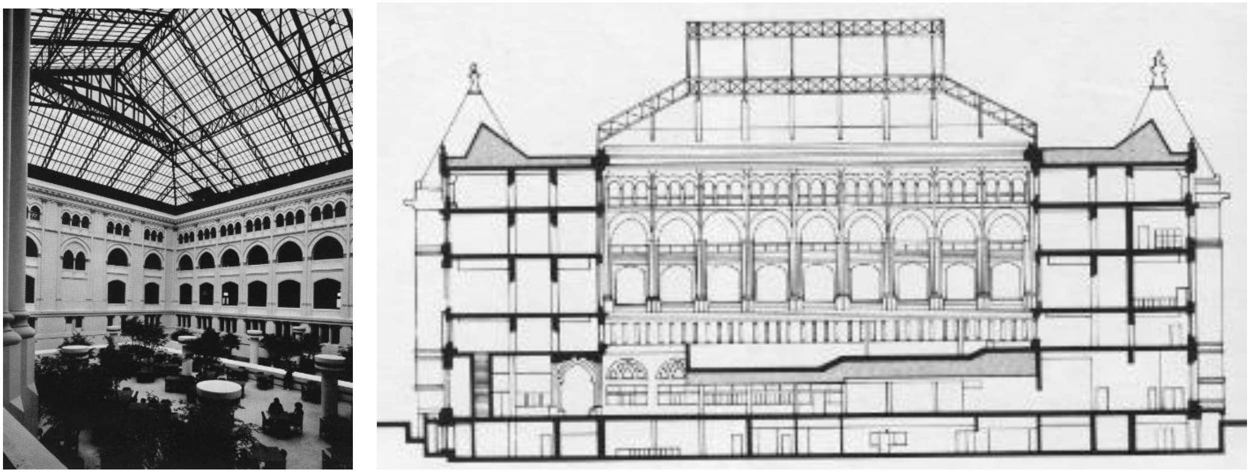

Figure 10. Erie County Community College, atrium. Source: Bednar, 1986

According to Bednar (1986), this refurbishment reduced energy expenditures by almost 50 percent. As a result, there is a great community space for the students and occupants of the building that protects from the harsh northern climate and brings new activities to the building.

B. Mercantile Wharf Building, Boston, Massachusetts

Six-story apartment building was designed by Gridley James Fox in 1856 as an apartment building, having quite a depth plan of 30.5 m. Therefore, it was decided to hold a design refurbishing competition, where John Sharratt proposed to carve out the unuseful space in the centre of the volume to form a 7.6 m wide atrium and to place new shops on the ground floor, saving 121 apartments, but they had to be redesigned (Fig.11). Ground floor of the building became public, what is quite unusual for the apartment building, thus private residents lounges were placed on each floor at both atrium ends. Public retail spaces have got entrances from the surrounding streets and to the atrium, where was designed green quite area. Atrium becomes a meeting space for the occupants and pedestrians alike.

Figure 11. Mercantile Wharf Building, atrium view. Source: Bednar, 1986

C. Addison Wesley Longman Headquarters, Harlow, United Kingdom

This new generation office building with three blocks separated by atriums was built in 1996 as energy efficient and achieved top BREEAM rating (Fig. 12). It can be called “sustainable” due to its energy efficient mechanical and electrical systems and the usage of renewable materials.

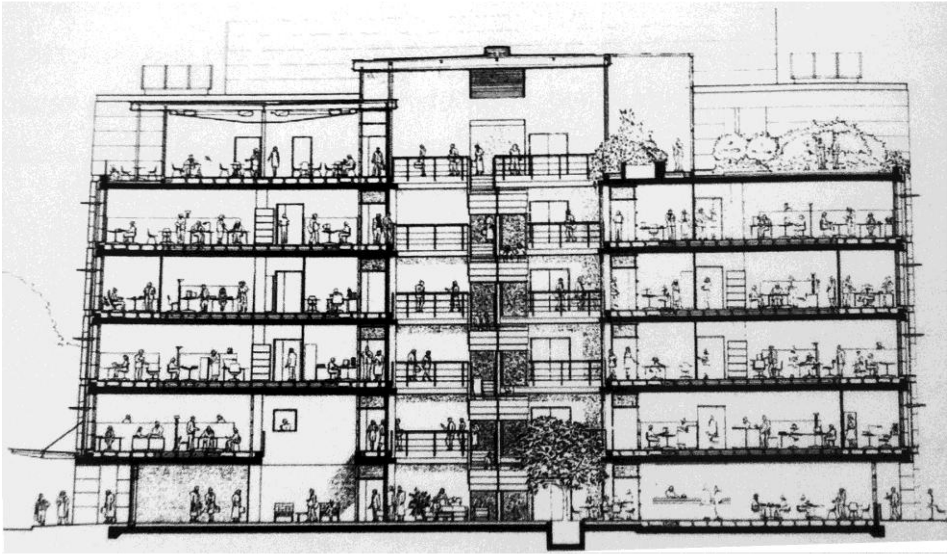

Figure 12. Longman Headquarters section. Source: AJ 30.5.96, 1996

All the blocks of the building have shared facilities such as café, fitness centre and print rooms on the ground floor, offices from first to fourth floors and with a restaurant on the top level.

For construction was chosen white in-situ concrete, which provides thermal mass for passive cooling. Cross ventilation strategy induced by the stack effect of the space is used in the building. There are manually openable air inlets in top and low levels windows, which allow air to flow through the open plan offices to the atrium. Vents on the rooftop can adapt their opening orientation to befit the prevailing winds. Consequently, all the indoor spaces have got natural ventilation, except of the areas with high internal gains, such as meeting rooms and restaurants, where cooling is necessary.

In summer windows on the top levels are mostly kept open to allow natural ventilation and night flushing of the concrete structure, exposed to the sun. According to Shum (1998), these exposed slabs are sensor controlled to 22^{o}C, but monitoring has shown that night flushing is rarely necessary. Exterior shading devices in combination with internal blinds reduce direct solar rays, penetrated inside the building. Figure 17 shows summer day strategy: open top windows create stack effect, which induces air from offices into the atrium. Induced cross flow provides fresh air to the office spaces, that in combination with radiant cooling from concrete slabs of the ceiling help to achieve comfort temperature. Shum (1998) took some spot measurements in a warm day in June, that show that the temperature conditions was always about 3 to 4^{o}C below outside, where it was 28 - 30^{o}C. Installation of powerful fans on the rooftop can help to reduce the indoor temperature.

In cold season offices are heated by manually controlled heaters, installed on the buildings perimeter in combination with fresh air, which is heated to 18^{o}C and goes through underfloor vents. Unfortunately, it dries the air and reduces the humidity level, making environment conditions less comfortable. Atriums are heated by low-energy underfloor heating to keep at least 14^{o}C that helps to avoid condensation problem. Also, warm air from offices exhausted to the atrium, increasing temperature (Fig. 13). Good building insulation and solar shading, which allows low winter sun to provide heat gains, help to attein comfortable conditions.

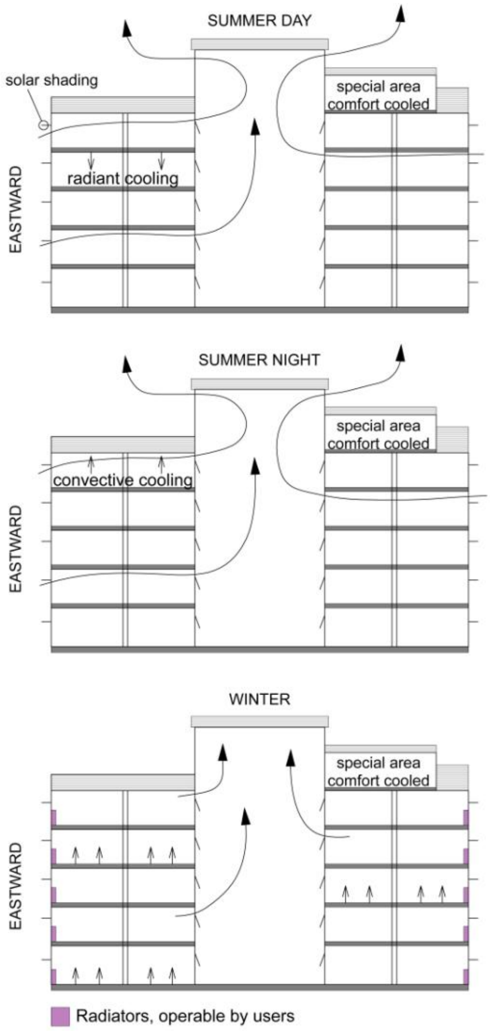

Figure 13. Ventilation strategies. Source: after Shum, 1998

Thus, the performance of this building with its atrium can be as an example of the correct application of sustainable principles in office buildings. As a space itself in improve communication between the occupants, bringing more contact to them, that positively affects on worker efficiency. Atriums became central parts of the building, providing comfort to the residents and improving building energy performance.

CONCLUSIONS

Reduce energy consumption of the buildings can be reached by decreasing heating needs and losses, using atrium's buffer effect, and refusing air conditioning by shading the space between buildings and using natural ventilation.

Covered space creates pleasing environmental conditions throughout the year. The comfort level can be reached by strong cross-ventilation and stack-effect in summer and pre-heated humidified air in winter. As the demands vary with seasonal change, a combination of strategies should work with adoptable devices, such as louvers and individually controlled heaters.

The atrium conserves the old building`s façade and allows for the recycling of the existing building stock. It gives a new special identity to existing historical buildings. Effective integration of old structures and new design improvements leads to economical benefits, new purposes and people`s enjoyment.

Effective use of plants and water provides cooling and refreshing the area. Also, it has their romantic and sensual quality that attracts people to get inside the space. The noise of the water covers other reverberations of the atrium space.

Atrium improves work and lifestyle conditions for the occupants, becoming a "living room" of the buildings. It infiltrates to the life and activities of the existing buildings, bringing enjoyment and comfort. Covered spaces shelter from cold winds in winter and sun`s penetration to warm the space in summer. Space invites people and offered more possibilities for recreation in any season and time of the day.

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