SOLAR CONTROLE STRATEGIES FOR CONTINENTAL CLIMATE OF MOSCOW

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Abstract

Moscow is situated in a continental climate zone, where there are hot summers and cold winters and there is a big difference between daily maximum and minimum temperatures through the year. Started the course of Sustainable Environmental Design I was trying to find design solutions, which can be used in Moscow climate. Particularly, in this research paper I want to answer the question if there should be employed some solar strategies in Moscow climate and the way, how they can be used. Pursuant to the inquiry, made by one Russian newspaper, in Moscow 73% of office buildings use air-conditioning. Also, in summer 2013 costs of energy usage increased on 12%. These prove the need in reducing energy consumptions. One of the ways is to involve solar control devices to deal with high energy demand on cooling in summer and heating in winter.

First, there will be a description of vernacular traditions of Russian architecture, because it can provide better understanding of existing problems and a history of dealing with them. Second, the description of Moscow climate and its features helps to find right strategies. Next, main types of solar shading devices and their application in Moscow climate will be described.

Keywords: office building, night shutters, shutters, overhang, shading

ПРИМЕНЕНИЕ СОЛНЦЕЗАЩИТНЫХ УСТРОЙСТВ В ОБЩЕСТВЕННЫХ ЗДАНИЯХ МОСКВЫ

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Аннотация

В Москве около 73% офисных зданий используют кондиционеры. Зачастую дизайн здания, материалы и конструктивные особенности помогают заметно снизить расходы на электроэнергию. В данной работе рассматривается использование наружных жалюзи и их влияние на среду внутри здания. Кроме того, некоторые виды жалюзи могут использоваться как ставни для снижения затрат на отопление в холодное время года. Как показывают расчеты, даже самые простые технологии могут снизить месячные затраты на кондиционирование на 26%, а отопление на 5%.

В статье исследуется традиционная архитектура, для лучшего понимания проблемы, климат Москвы, для применения необходимых методик и рассматриваются различные виды солнцезащитных устройств и их применение в Москве.

Ключевые слова: офисные здания, наружные жалюзи, ставни, солнцезащитные устройства

VERNACULAR TRADITIONS

Talking about any design innovations it is useful to look at the vernacular traditions of the certain area, if there were used some strategies before. Therefore, it was decided to look at Russian history of shutters, which are known from 16 century, before the development of modern glass. In vernacular Russian architecture, especially in village houses, shutters were spread everywhere. There were two types of them. Louver shutters with horizontal slats helped to admit light and air, but to keep out rain and direct solar rays. In summer people kept their windows opened, while the shutters were closed to let the fresh air come inside the house. For Russian village house it was necessary to keep the heat inside during long cold winter. Solid panels shutters could protect from wind, cold and heavy snowfall, when snow could reach the roof level. Also, occupants closed the shutters and upholstered the space between with insulation.

Originally they were constructed not only for light and heat control, but they also provide glass protection and privacy. When a family used to leave the house for a long period, shutters were nailed down. In some village houses you can see double-shutters, louvers and solid, which helps people to deal with summer heat and winter cold at the same time. You can close louvers while solid shutters will stay opened. Of course, it provides more control and as a result more comfort to the occupants. Then, shutters started to become a decoration element – wooden with fretwork and paintings, bright colored they told about the prosperity of the family. Even in 19th century windows were not openable, people took out all the glass with a frame in summer time and used shutters to protect houses from solar rays. Wooden log house with colourful carved shutters becomes a traditional design of the village houses that used up till now (Fig. 1).

Figure 1. Traditional shutters

CLIMATE PECULIARITY

Moscow is located in a continental climate zone latitude 55^{o}N, where there are hot summers and long cold winters. In mid-summer the average temperature is about 24^{o}C, but hot wind can increase it up to 30^{o}C. In winter the temperature is often below zero, and there are only six hours of daylight.

Weather data for Moscow was get from the Meteonorm global meteorological database. Figure 5 presenting monthly temperatures through the year. The variations of outdoor temperature show that the annual cycle can be divided into three periods: 6-month (from March to May and September to November) of warm weather with daily mean temperatures +5 to +18°C, three summer months with mean temperatures of 18-25°C and higher degrees and a cold period from December to February inclusive with daily temperatures of -25 to -5°C below zero (Fig.2). Summer daily temperature can be very various each year. According to Moscow weather station, in summer 2010 there were 43 days with temperature above 30°C, while next year there were only 14 days with such temperature records.

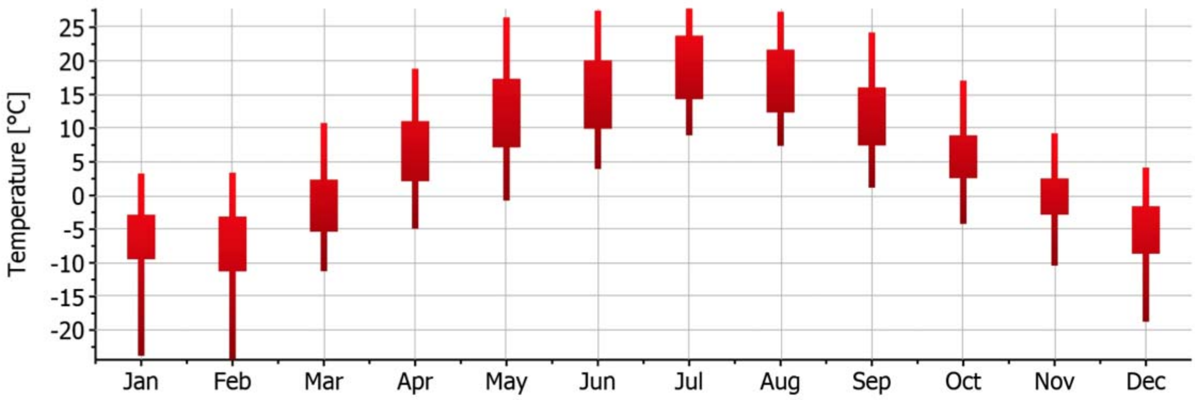

Figure 2. Monthly temperature data. Source: Meteonorm 7

Sunshine duration is various through the year. According to the data from Meteonorm, in winter there are only 7-9 hours of astronomical sunshine duration, while in summer this value rises to 17 hours per day (Fig. 3). There is also a big difference between monthly radiation in different seasons. Weather data for Moscow generated with Meteonorm 7 (Fig. 4) indicates that from December to February inclusive the amount of monthly global radiation on horizontal surface is below 20 kWh/m^2, comparing to summer months with about 160 kWh/m^2 global radiation, where about the half of its amount is diffuse solar radiation, while in vertical surface on summer months same value staying about 90 kWh/m^2 and 35 kWh/m^2 in winter. Assumed that most of solar shading devices mainly protect from direct solar radiation, it can be considered that even when there is no direct solar rays in summer building is still exposed to a quite high amount of solar radiation.

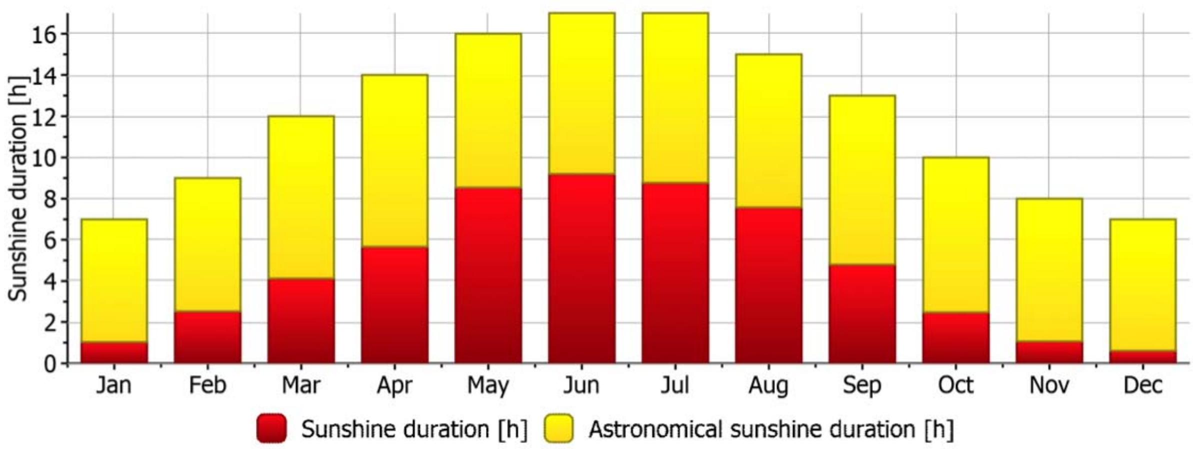

Figure 3. Sunshine duration. Source: Meteonorm

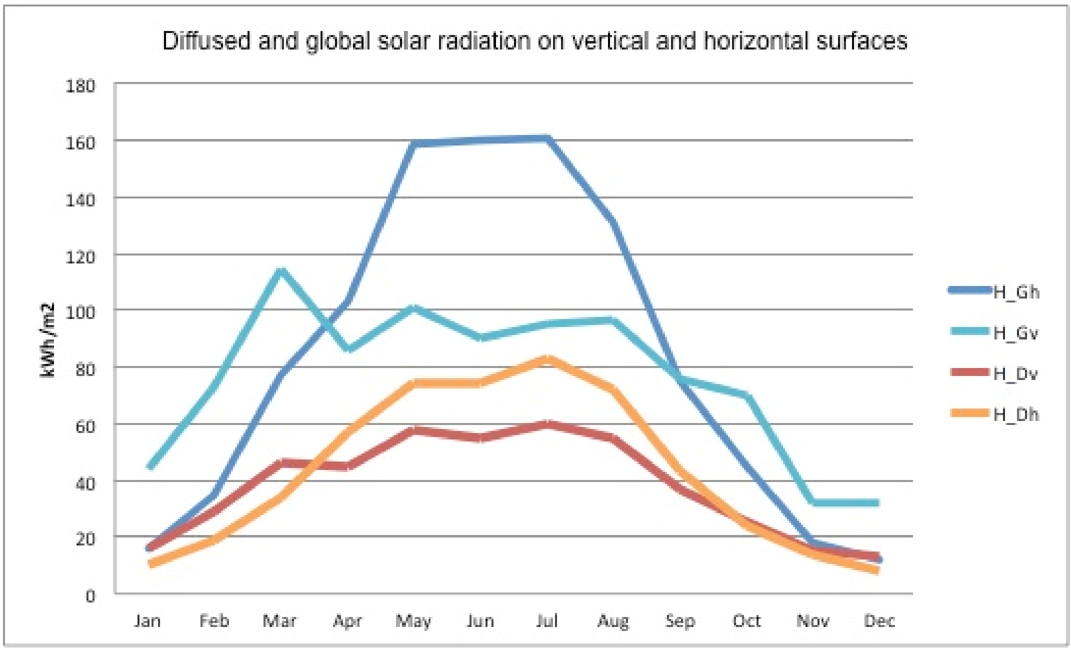

Figure 4. Global and diffused solar radiation in Moscow on vertical and horizontal surfaces. Source: after Meteonorm 7

Summarize these data, it can be resumed, that solar control strategies should be based on reducing the amount of solar radiation in summer time, but allowing direct solar rays to reach inside spaces in winter and to increase daylight factor.

MAIN STRATEGIES

Basing on previous climate characteristics, several solar goals for Moscow commercial buildings can be set: to allow solar radiation to reach the window in winter; to block some amount in summer and prevent overheating; to diffuse daylight; reduction of glare; improvement the distribution of daylight in a room. All this strategies are using to provide more comfort to building`s occupants and to cool the building effectively, that influence building energy performance and, as a result, reduces the peak-cooling loads in the building. In Moscow climate the amount of solar radiation is not significantly high, therefore correct solar techniks can help to completely abandon air-conditioning equipment.

In general, external shading devices can be subdivided into several types: movable or fixed; horizontal or vertical.

Movable solar shading devices are consists of mechanism that can be with automatic or manually regulation. In both cases it does not approach Moscow - it gets spoiled quicker because of the specific now is problematical in Russia. Therefore it was decided not to mention them in this research.

Talking about fixed shading devices, it can be said that they play a huge part in building design, because they are embedded in it. They are mostly effective on the South-facing windows. The main aim for the architects is to calculate carefully the size and position of such devices, because the mistakes will be felt by the occupants for the whole building`s live period. Also, panel finish is important.

"Reflective blinds may (with clear glass) reflect heat back out, while absorbing blinds will become warm quickly".

(CIBSE, Daylighting and window design Lighting guide LG10, 1999)

Baruch Givoni, Israel architect, the specialist in bioclimatic architecture, analysed the efficiency of different types of shading devices in different orientation and made a conclusion, that vertical shading is less effective than the horizontal.

"Advantages of horizontal projections over vertical projections are: (i) vertical device is not applicable for shading the whole length of façade; (ii) vertical device reduces daylight penetration more than horizontal projection; (iii) vertical projections will reduce the extent of external view"

(Givoni B.; Man, climate and architecture, 1969)

For Moscow climatic peculiarity horizontal overhangs on South facades can be more useful, because they allow low sun in winter to enter windows and they blocks higher summer sun. Such devices consists of a light-reflective shelf part under the window, thereby they can shield the window lower it from solar radiation and at the same time reflect sunlight from the upper surface on the ceiling inside the building. It helps to diffract the daylight in indoor spaces, also dealing with glare.

Wulfinghoff D.R. (1999) found that to be effective, they must be much wider than the windows, in the direction along the wall, to account for the sun's motion from east to west. Also, a single shelf should have enough width that will be proportional to the windows height to block the necessary amount of solar rays. Otherwise several horizontal planks can be installed behind the window. Paul Littlefair (2003) suggests that with a South facing window a relatively small overhang (depth equal to 0.6 times the window height) can be effective. For East or West facing window the overhang can still provide valuable shading if it is a deep one.

In winter low solar rays can pass through the window area and fall on the work surfaces of the room, leading to a possible glare. Therefore, shading shelves are better to combine with additional solar protection. New RetroLux internal louvers allow to block high solar angles and do not block winter sun, dealing with glare (Fig. 5). They consist of two parts: first shields overheating rays, second deflects daylight to the ceiling. Each plank of the louver is designed to have minimal height to provide best vision outside. As a result they do not need to be rotary to close completely the window area.

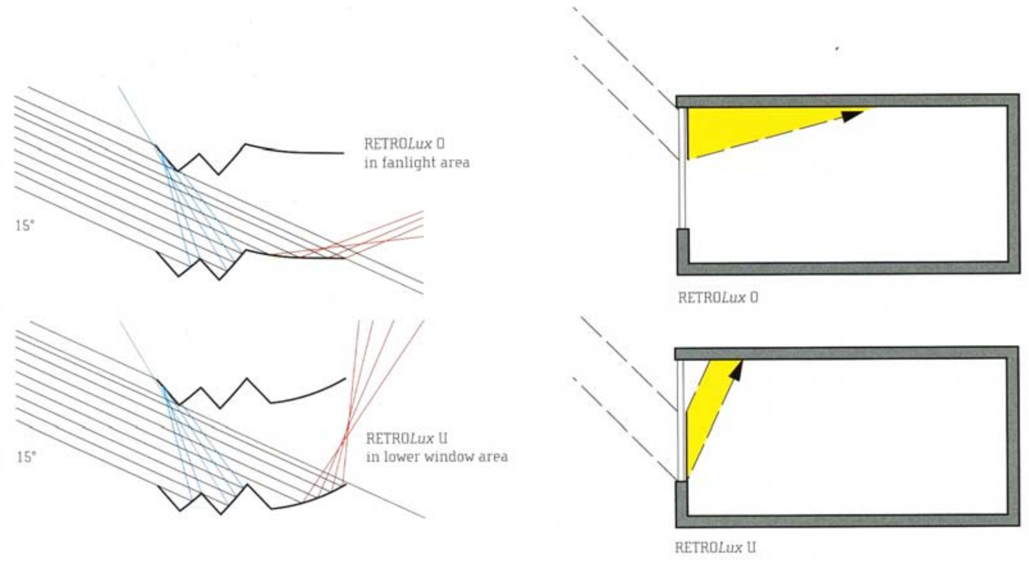

Figure 5. RetroLux louvers. Source: Helmut Koster, 2004

"Fixed vertical projections or screens can be effectively with east- to west-facing windows, especially if the vertical fins are inclined towards the north to screen sunlight coming from the south"

(CIBSE, Daylighting and window design Lighting guide LG10, 1999)

Also, vertical panels can shield north façades from summer solar rays in morning and evening. Under the climate investigation and basing on own experience, there is no paramount necessity to use some external solar protection on these facades.

There are also some types of shading devices, which can be place inside the window to reflect short wave radiation back out through the glass.

"Darker blinds or curtains may reduce solar penetration into the space and may be helpful, but not as effective as exterior shading because it still convert most of the sunlight into heat within the building envelope since heat has already penetrated the building"

(Kamal M.A.; Architecture – Time, Space and People, 2011)

But blinds placed between two glazing panels are not so effective in Moscow, as external shading devices, because the best way to reduce solar radiation is to block direct sun before it will reach the window surface.

To see the effectiveness of the overhang on the South façade, some simulations of a room 8 on 14 meters were done (Fig. 6). This potential "box" is situated in the middle of a building, with one South-facing window, window-to-wall ratio is 50% and internal conditions, such as occupancy and appliances are applied. Figure 7 shows blocking solar rays with overhang 800mm during day hours from May to August. TAS simulating application was used to calculate the difference in solar radiation and cooling loads (thermostat set on 20-26°C) with and without overhang. Results for June show that reducing solar gains on 31% helps to decrease cooling loads on 26%.

Similar calculations were done for typical winter month, where overhang was transformed into night shutter (Fig. 7) from midnight to 7:00 with the same internal conditions. With 2 cm wooden shutters U-value of the window was improved from 1.63 w/m^{2o}C (double-glazing argon filled glass) to 0.98 w/m^{2o}C. This reduces heating loads during the night on 5.3% (Fig.8), but it can be improved by insulation of the shutters, decreasing ventilation rate and changing the minimal require of the set temperature during unoccupied hours.

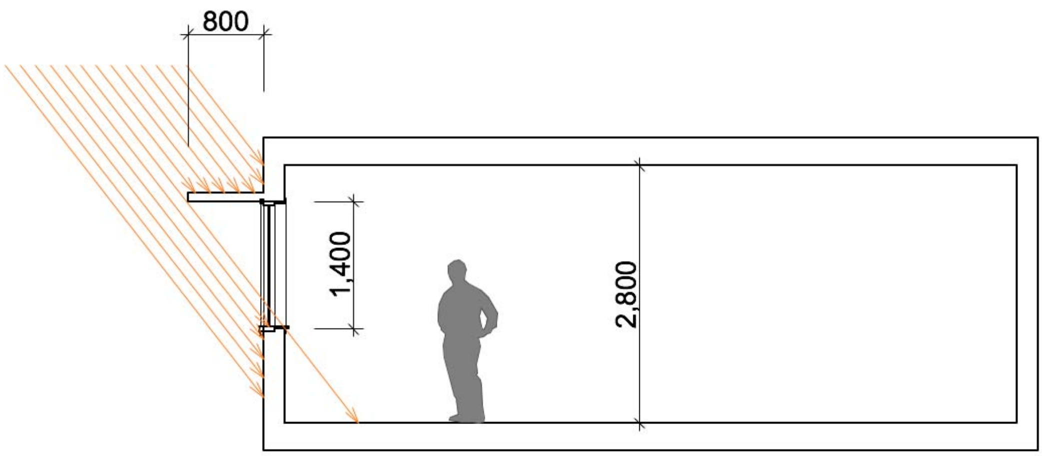

Figure 6. Section of a room in an office building

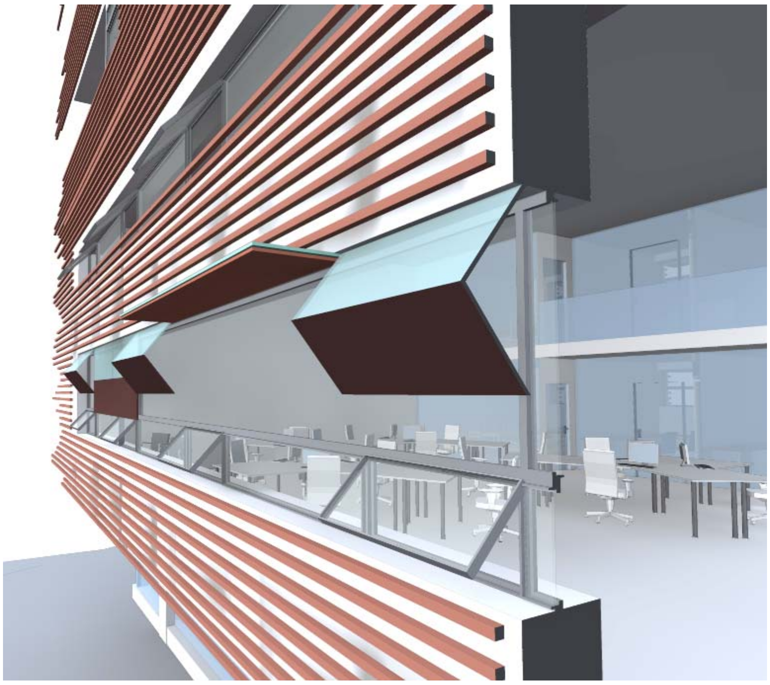

Figure 7. Sketch scheme of the transforming overhang

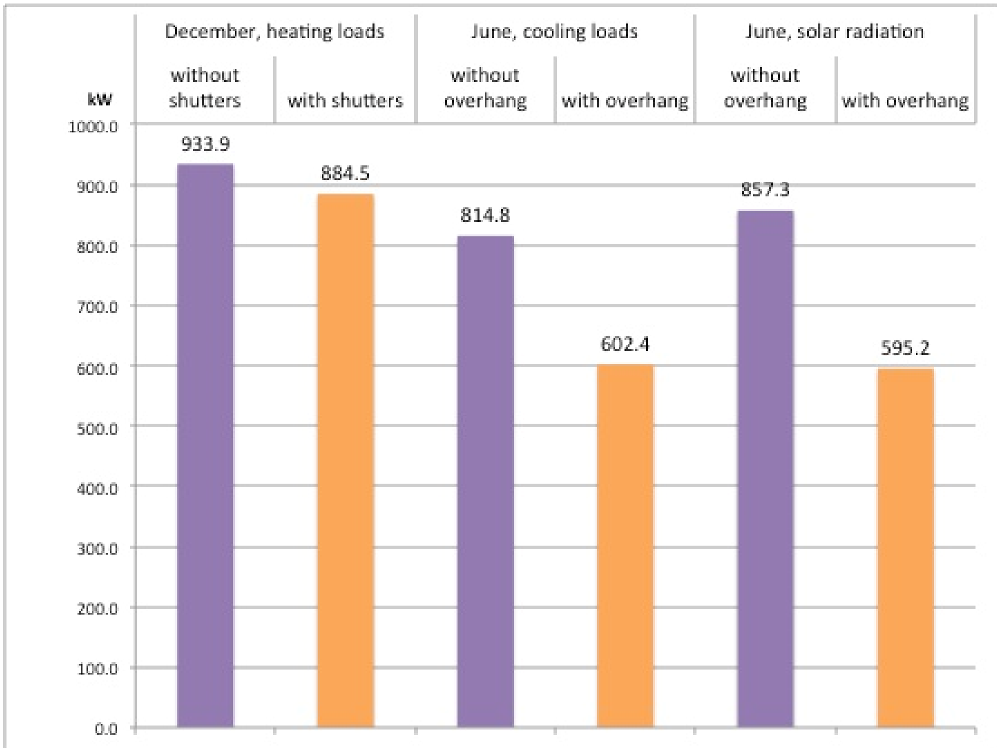

Figure 8. Monthly loads, showing the difference between base case and its improvements

CONCLUSION

Well planned external shading devices are the best way to solve many problems from reducing energy consumptions to providing more comfort to the people inside. In Moscow climate these strategies should be used very careful to avoid reducing daylight that could result increasing usage of electric light. As it was found in this research paper, best results will show horizontal overhangs on South facades, because they concentrated on blocking high solar angles and allowing low winter sun to heat the building, that reduces monthly cooling loads on 26%. In combination with internal louvers mainly all the goals, listed in first paragraph chapter "Main strategies" could be solved. It is not necessary to cover North façade with cladding, West and East facades are harder to shade from morning and evening sun, but it can be done by designing vertical panels. Also, during the night in winter some types of overhangs can be transformed into night shutters, that reduces monthly heating loads on 5%.

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