Double enclosure: application for a commercial building in Athens, Greece

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ABSTRACT

The goal of this study was to suggest a low-density typology for commercial buildings to be applied in the cultural and climatic context of Athens, Greece, with minimal demand for conventional cooling. More specifically a typology of “double enclosure” was studied with self-contained structures sheltered within an outer shell. The research develops through studies of built examples in Athens and analysis of the parameters affecting thermal comfort and adaptability. Dynamic thermal simulations were used to gain understanding of the energy behaviour of the double enclosure typology. The analysis conclusions were incorporated into an indicative design proposal, which was then assessed in terms of thermal and ventilation performance through computational simulations.

1. INTRODUCTION

Buildings housing retail spaces are particularly energy consuming in their majority, as the use of air-conditioning and artificial lighting is considered an inevitable necessity. Generally, due to high internal gains, retail spaces are susceptible to overheating. In addition in many countries the shopping area per person has increased significantly. The aim of this study is to investigate whether the typology of enclosing self-contained structures in an outer shell can be applied in Athens. Two main aspects of this typology will be studied: first, its potential to create indoor retail and recreational spaces achieving their environmental requirements without extended use of artificial means, second, its capability to offer semi-outdoor zones around the shops that will perform as thermally comfortable social spaces and as transitional zones facilitating the body to adapt during the passage from outdoor to indoor conditions. The final aim is a stimulating range of spaces featuring diversity of functions and thermal conditions.

2. CLIMATE CONSIDERATIONS

Athens is located at latitude 38° north and longitude 23° 4’ E. The climate is considered typically Mediterranean with long periods of clear skies throughout the year. Winters are relatively mild with average temperatures ranging at 7-14°C (Fig.1). Summers are rather severe with temperature range around 23-32°C, however temperatures over 35°C are not uncommon. Global radiation on a horizontal plane in summer may rise above 800 W/m², while in winter values may vary significantly, between 200-500 W/m² (Fig.1), depending on cloud cover. The prevailing wind is north with average speed between 2.5-5 m/s for most of the year. The climate is dry with average humidity at 3 pm in summer around 32%. Usually from early spring to late autumn the weather allows the use of outdoor spaces. The desire for being in outdoor or semi-outdoor spaces is therefore embedded in the culture.

Figure 1. Monthly diurnal averages of air temperature and solar radiation in Athens (Source: Meteonorm V4.0 and Weather Tool software).

The high summer temperatures indicate that cooling of spaces during the hot season should be a priority. However the low relative humidity values, the quite wide diurnal temperature range and the high levels of direct solar radiation in summer create potential for application of passive and low energy cooling techniques such as evaporative cooling, night time ventilation and shading.

3. LESSONS FROM BUILT PRECEDENTS

Three case studies of buildings housing independent retail businesses under the same roof were studied through site visits. They were selected for representing characteristic typologies and as popular examples among the public. The analysis aimed to determine the issues involved in retail and how design decisions made to accommodate them impact the energy behaviour of the building. The main observations are presented here briefly. The first example is a 19th century semi-outdoor arcade...
housing the stalls of a fish-market (Fig. 2a), the second a mid-70’s two-storey mall with open balconies linking the shops (Fig. 2b) and the third a high density, introverted mall housing over 200 shops completed in 2005 (Fig. 2c).

Even though the fish market is a free-running structure it functions successfully around the year. Temperatures are often outside the conventional comfort zone however visitors do not seem to be affected. This is partly because of their usually short stay in the space but mainly because they perceive it as a naturally ventilated extension of the outdoors therefore their expectations for thermal comfort are confined to basic sheltering from sun and rain, allowing them to accept a wider range of conditions. The second example is popular because the open balconies allow visual contact between the shops and the street. However it presents a number of problems. The display windows, necessary for promoting the merchandise, create extensive glazed areas on all facades that are exposed to cold winds and solar radiation. This, in addition to continuous opening and closing of doors increases the heating and cooling loads of the shops. Another noted problem were the abrupt transitions experienced by visitors when moving from the controlled environment of the shops to the outside and the opposite. In the third example all the shops and circulation zones are air-conditioned so there is no issue of thermal transitions. However as both types of space are treated the same, in terms of materials and ventilation, visitors in the circulation areas also have expectations for closely controlled temperatures. This reduces significantly the acceptable comfort range and increases the need for mechanical air-conditioning around the year. Also the high density of space and deep plan of the building do not facilitate the dissipation of excess heat gains.

4. DESIGN CONSIDERATIONS AND STRATEGIES

4.1 Design brief
In order to create a lively and stimulating space a variety of functions were combined in the design: small retail spaces for the trading of durable goods (opening hours 09.00-21.00), a market space with stalls for the sale of fruits and vegetables (opening hours 08.00-15.00), cafés (opening hours 09.00-21.00), storage spaces, public resting areas and circulation spaces linking the above.

4.2 Design concept
The typology of double enclosure offers two basic types of space: located within the self-contained structures and created directly under the outer envelope, the latter will also be referred to as intermediate space (Fig.3). For the intermediate space to be beneficial to the energy profile of the building only passive and low energy techniques should be used to condition it while at the same time it should shelter the internal structures from sources adding to their cooling and heating loads.

The conditions within the structures will be easier to control as they will be fully enclosed and the outer envelope will have a buffering effect on them. Seating spaces for the cafés, to be used during the heating season, as well as retail spaces can therefore be housed there. On the other hand the intermediate space will be more influenced by outdoor conditions, especially if the envelope is of lightweight construction, and can be converted to semi-outdoor by opening parts of the outer envelope.

Research conducted by Nikolopoulos and Steemers (2003) demonstrated that psychological adaptation is increasingly important in outdoor spaces. This is because of parameters such as naturalness, expectations, duration of exposure, perceived control over environment and environmental stimulation helping occupants adjust to their environment. By converting the intermediate space to semi-outdoor the influence of these parameters can be exploited to enhance thermal comfort. Spaces that are used for leisure when the weather allows it or for short periods of time, such as seating areas of the cafés for the cooling season and public resting areas, would be more suitable for the intermediate space. Circulation zones located in the intermediate space can also function as transition zones between the outdoors and the controlled environment of the internal structures in order to avoid abrupt thermal transitions. Finally, the stalls can be located in the intermediate space as well, as they are used only daytime hours and require direct access facilitating the quick purchase of basic goods.

4.3 Environmental requirements
Cooling of spaces will be the focus of the design proposal. A survey conducted in Athens has shown that 28 °C can be set as the upper comfort limit for interior spaces in summer (Yannis, 2000).

Also, research by Arens (1980) indicates that in outdoor spaces occupants, when relaxed, can feel comfortable at 32°C, the average maximum for Athens in summer, in shade and with a wind speed of 3m/s or over.
4.4 Eliminating the need for space cooling
Dynamic simulations were performed using TAS EDSL software in order to define the effect of different strategies on the internal structures. A model with two-storey structures was used separated into four zones as in figure 4. In each space one façade is fully glazed simulating a window display. North and south facing windows were preferred as they receive the lowest amount of solar radiation in summer and are easier to shade respectively. To test the shading effect of a second envelope on the glazing two simulations were performed on a typical summer day, first with the structures alone (A1) and then with the addition of an adiabatic opaque outer envelope (A2) as shown in figure 6. The results (Fig. 5, 7) show an average temperature drop of 2.5 K in all zones with the addition of the envelope. Another simulation was performed this time using the ground and the ambient air as heat sinks through coupling with the ground and night-time ventilation respectively. The same geometry as in simulation A2 was used with settings as in Table 2. The results (Fig. 8) show that the ground floor north oriented space is the coolest space in summer, with maximum temperature on an average summer day at 29.2°C making it the most suitable for the shops. The upper north space can then be used for storage. The south spaces can take advantage of the low altitude winter sun therefore are adequate for the cafe winter spaces. The suggested arrangement is diagrammatically shown in figure 9. Low energy techniques can also be used to further improve summer comfort in the interior structures such as ceiling fans or further coupling with the earth through earth tubes.

4.5 Treating the intermediate space
Thermal comfort in the intermediate space can be achieved controlling parameters affecting psychological adaptation and microclimate. As showed by Nikolopoulos and Steemers the intermediate space should be at least partly open to the outside and include natural and stimulating features, such as vegetation elements, variation of light conditions and unlimited views to the outside. Also, to cater for perceived control, a selection of sub-spaces with different levels of solar radiation and air movement should be created for visitors to choose from. To improve the microclimate of the space solar control should be applied on all spaces protecting occupants both from direct solar radiation and from the radiant load of overheated surfaces. Air movement and temperature can also be controlled seasonally taking advantage of prevailing winds or applying locally low energy cooling systems based on evaporative cooling.

Table 1. Settings applied for simulations A1 and A2.

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<tr>
<th>Parameter</th>
<th>Setting</th>
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<tbody>
<tr>
<td>Opaque elements U-value</td>
<td>0.04 W/m2K</td>
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<tr>
<td>Glazing type</td>
<td>single</td>
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<tr>
<td>Internal conditions</td>
<td>no gains or ventilation</td>
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Table 2. Settings applied on simulation A3.

<table>
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<th>Parameter</th>
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<tr>
<td>Walls, ceiling U-value</td>
<td>0.23 W/m2K</td>
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<tr>
<td>Ground level floor</td>
<td>non insulated concrete slab</td>
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<tr>
<td>Glazing type</td>
<td>double low-e</td>
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<tr>
<td>Internal conditions</td>
<td>Retail unit: 30 W/m2, 1.3 ach</td>
</tr>
<tr>
<td>Night time ventilation</td>
<td>20 ach during 19.00-07.00</td>
</tr>
</tbody>
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Figure 4. Geometry of internal structures model in TAS.

Figure 6. Geometry used in simulations A2 and A3.

Figure 7. Results of simulation A2.
5. DESIGN APPLICATION
The proposal aims to a simple and “readable” design. The internal structures housing the different functions are arranged in two rows along the east - west axis and spaces are arranged in two-storey structures according to the diagram of figure 9. The ground floor plan is shown in figure 10. The stalls are located towards south under the winter cafes spaces providing views through the space. By being in a more confined space cooling techniques such as artificial mist can be applied more efficiently. In addition they benefit from the thermal mass of the concrete slab of the first floor and the concrete side walls. Large versatile spaces are created towards east and west that can be used for recreation or cultural events. The occupants resting in these spaces can choose their position and duration of stay and relocate themselves according to the time of day and season. The first floor consists of secondary spaces, like storage towards north, and café winter spaces towards south. A basement is not created so that the floor of the spaces is in contact with the ground benefiting from its thermal mass.

The large surface of the roof of the outer envelope can be exploited according to needs. It can feature a planted roof to improve the site’s microclimate or a roof pond to provide a cooling effect on the intermediate space. Solar collectors or photovoltaic panels can also be mounted there. Part of the roof extending over the south façade is composed by a retractable shading device so as to regulate the solar access of the south facing spaces. The west and east facades feature large solid surfaces to block the low altitude sun in summer. The south and north façades do not feature any solid elements to allow daylight into the building and views across the spaces. The south façade will be permanently open while the north façade is completely glazed and operable so that different parts in different heights can open to regulate the prevailing northern wind according to seasonal needs. In summer the glazing will be fully open to allow a breeze into the intermediate space and nighttime ventilation of the structures.

Passive Downdraft Evaporative Cooling (PDEC) towers are installed in front of the cafes and at the south west part of the building to create “pools” of cool air. To maximize the cooling effect wind flow through the spaces is blocked by glass panels or vegetation and lowering of the area into the ground respectively. Rough materials such as stone and vegetation are used in the semi-outdoor spaces to increase the naturalness of the space.

6. THERMAL PERFORMANCE
The thermal performance of the shops in their final configuration was assessed using TAS software. Frequency macros were run to calculate the number of occupied hours (365 days, 09.00-21.00) with resultant temperatures outside the set comfort zone. A second run of simulations was then performed including a thermostat in order to calculate the yearly loads for cooling.
7. CONCLUSION

The analysis and simulations presented show that the typology can be applied in the climatic context of Athens accommodating the environmental requirements of different spaces. The analysis results showed that passive features and low energy techniques can be combined in the design so as to eliminate the need for a conventional cooling system in summer. Tests performed for the heating season also showed satisfactory results. The control of occupants’ expectations for thermal comfort and their ability to adapt to the different conditions form an important part of the design. Finally the intermediate space forms an architecturally interesting environment that is sheltered from sources of discomfort therefore facilitating the transition of visitors from outdoor to interior spaces.

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REFERENCES

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