Adaptive Skins and Microclimates

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ABSTRACT: The paper reports on a project that served as a key learning tool for this year's post-graduate teaching programme. Starting with fieldwork and design proposals for sites in London, student teams proceeded with the design and construction of a small structure that was erected in April 2004 on the island of Santorini in Greece.

Conference Topic: education and technology transfer; comfort and well-being in urban spaces
Keywords: urban microclimates, outdoor comfort, adaptive skins, environmental software

1. INTRODUCTION

The Architectural Association Graduate School's Environment & Energy Studies Programme (AA EE) explores the application of sustainable environmental design at the level of the city and the individual building. An ongoing topic of investigation is the relationship between built form and environmental performance. A number of recent projects have focused on aspects of mixed-use development as part of a zero carbon emission strategy for urban environments. Field studies undertaken in the context of these projects and reported in other papers, [1][2][3][4], have revealed that the microclimatic attributes of the urban tissue vary widely within any given segment of a city. As a result the urban tissue accommodates distinct microclimatic niches of unknown and unpredictable variability. Such variability may be the outcome of built density and urban geometry. Both these factors affect solar exposure and air flow within the fabric of the city, and either of these climatic parameters can have a strong effect on the microclimate of a site. Microclimatic variability can be also the result of anthropogenic sources inside, as well as outside, buildings. A resulting problem for urban design, affecting both building design and that of open spaces, is that generalised models are of limited use in helping to characterise and assess local conditions so as to inform design. On the other hand, a promising inference is that a process of ecological regeneration could be initiated by local interventions aimed at creating pockets of improved microclimate which can contribute to reversing the negative effects of urban climate change. This is a corollary of the observation that distinct microclimates can coexist in close proximity within the urban environment without one negating the other.

The most significant microclimatic variations are commonly created by differences in sun and wind patterns. Such differences have an immediate effect on the sensation of thermal comfort or discomfort experienced by sitting, standing or moving around the spaces affected. But they also affect temperature, soil moisture, and plant growth, and these in turn contribute to the differentiation and characterization of the microclimate. The longer the exposure of an area the more marked may be the resulting microclimatic differentiation from an area not similarly exposed.

How can we compile a microclimatic profile of an area or site without having to embark on long-term measurements ? How much influence can we exert on the environmental variables characterizing a microclimate ? What means can we use to accomplish such modifications ? What are relevant applications? Sunshine duration and intensity, wind direction and velocity and the other environmental parameters all vary over time, both within the daily cycle and seasonally, but also from year to year. What adaptive mechanisms can we employ to respond to this dynamic ? how can these microclimatic tools become self-updating in their environmental behaviour ?

These questions provided the starting point for a learning process that combined theoretical, empirical and analytic studies as inputs to design proposals that were meant to be informed by environmental considerations from the outset. The lessons learnt and the design proposals developed in the course of this process are briefly discussed in the following sections of the paper.

2. ADAPTIVE SKINS & MICROCLIMATES

2.1 Context

The Adaptive Skins & Microclimates project was introduced in October 2003 as a vehicle for applying the theoretical concepts and analytic tools presented by the taught courses of the AA EE Masters Programme. The first stage of the project involved observations and measurements indoors and in open spaces around Central London. The objective at this stage was to investigate the mechanisms underlying different microclimates in the urban environment. The variability and cloudiness of London weather and the strong effect that wind patterns have on outdoor thermal comfort were early observations by the eighteen Masters students taking part in the project. These observations led to design briefs that ranged from explorations of adaptive clothing to proposals for urban pavilions and the creation of dynamic landscapes for pedestrians in the city.

Short-term readings of environmental parameters were undertaken in selected locations around London as part of diagnostic investigations and outdoor thermal comfort studies. Computer software that was introduced by the taught course for use on this project included: Meteonorm v5.0 for generating weather data [5]; Ecotect v5.2 software for 3-D studies of solar access, shading and daylighting and for analysis of weather data [6]; TAS for dynamic thermal simulation [7]; CFX-5 for air flow simulation [8]; and ENVI-met for outdoor microclimate simulation [9].

2.2 Adaptive Topographies

Following study of long-term weather data for Central London and short-term observations of sunshine, temperature and wind patterns on several central sites, one of the project teams focused on the concept of an adaptive topography that would vary in shape, in response to daily and seasonal variations of environmental parameters, with the aim of providing better conditions for outdoor activity [10]. Proposals for the south side of the Tate Modern Gallery in south London, Fig. 1, evolved following measurements around the site, Fig. 2, and simulations of microclimatic conditions using the Envi-met and Ecotect software, Fig. 3. Parts of the site have good solar access which is a very valuable commodity in a high latitude urban environment of variable sunshine availability. In London wind patterns are both variable and mostly disruptive. As air temperatures are rarely extreme in the city centre, protection from, or exposure to, wind, rain and sun are the deciding factors for outdoor activities. The thrust of the proposals shown in Figs. 1 and 3 is the creation of a dynamic landscape of variable topographic features and surface properties. The team conceived this adaptive topography as consisting of three complementary layers. The landform layer of

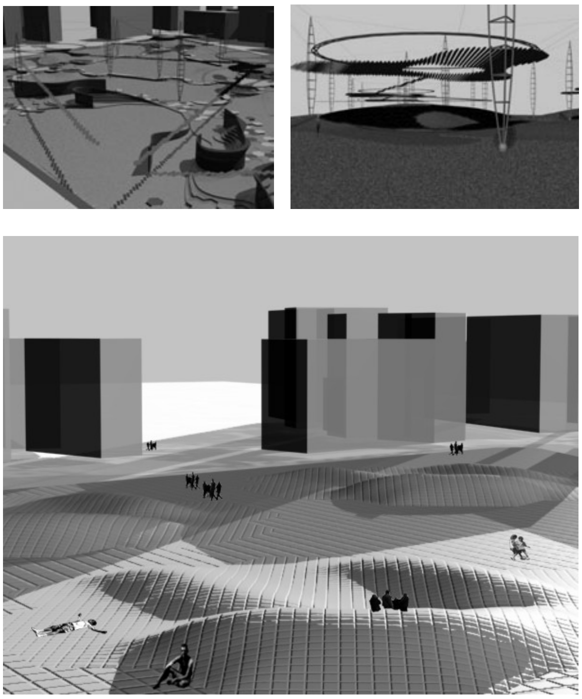

Figure 1: Views of parts of site on south side of Tate Modern Gallery showing proposed landform, parasol and activity layers.

Figure 2: Positions of measurements of air temperature, relative humidity and wind velocity as recorded by GPS around the Tate Modern site in south London.

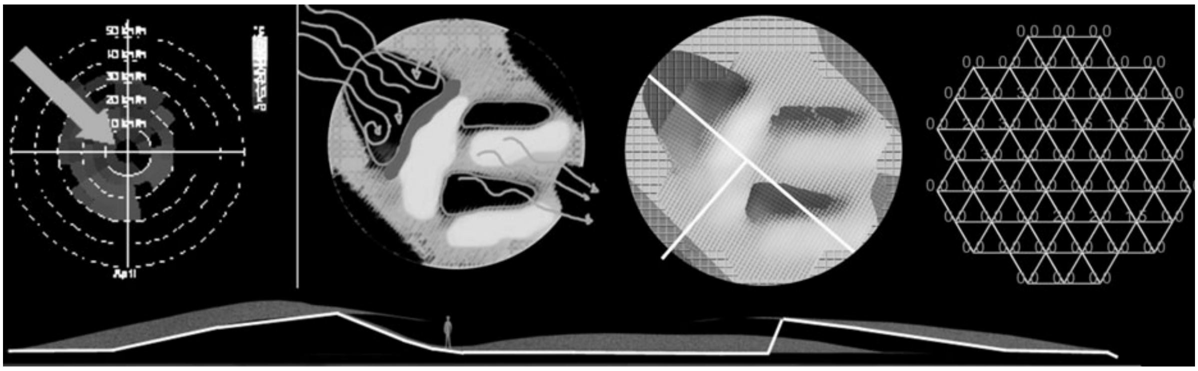

Figure 3: Landform adaptive strategies for typical April daytime conditions on Tate Modern site, London. Diagrams from left to right: wind (and sunshine) data translated into zones of wind protection and solar access illustrated on landform plan and section; the change in the altitudes of grid points is shown on the hexagonal grid (far right) and site section (bottom).

stabilised soil sits on an hexagonal grid that regulates upward or downward movement. Sections of points on the grid are moved upward to provide a wind shadow, whilst others may rise to improve solar access, thus dividing the site into areas of wind and sun shadow or exposure. Microclimatic simulations were performed for a range of typical London weather conditions to identify the range of movements and responses required from the landform layer. Figure 3 illustrates one of these instances. A parasol layer set some 6.0m above the landform is designed to provide selective rain protection or solar control as the case may be, Fig. 1 (top right). Various activity layers can then be inserted into the site combining architectural elements and outdoor furniture with complementary climatic properties, Fig. 1 (top left).

Complementary options were explored by a second team with proposals for outdoor elements and furniture for streets and parks, Fig. 4 [11].

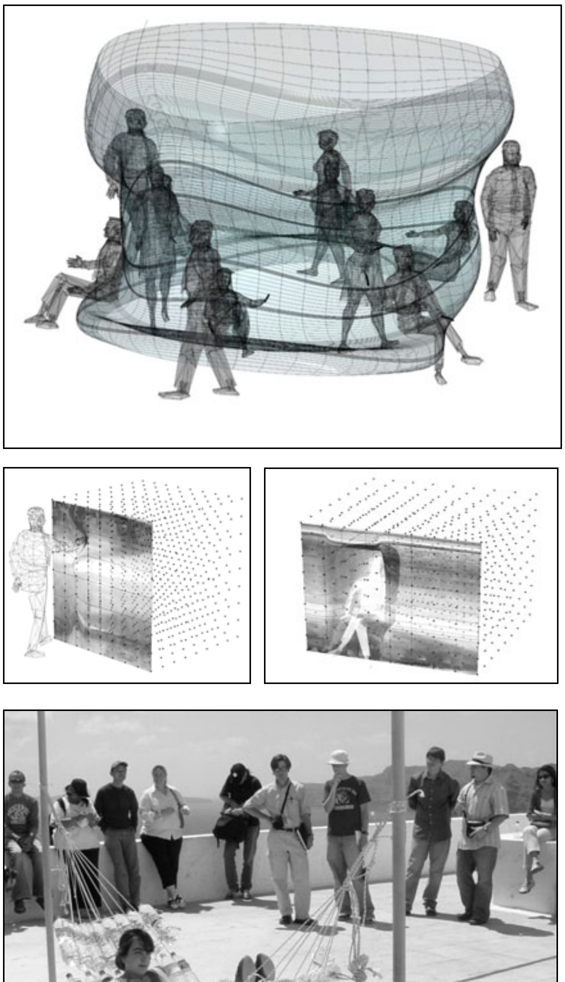

Figure 4: Proposals for producing warming or cooling sensations by conduction; (photo bottom) demonstration of variant using refilled plastic water bottles.

2.3 Urban Shelters

Observations of microclimatic effects around London squares, bus stops and other open spaces, Fig. 5, led two of the teams to designs for small pavilion-like shelters [12] [13] for use by passers-by or bus passengers. These were conceived as being composed of movable elements to provide the adaptive mechanisms, Fig. 6.

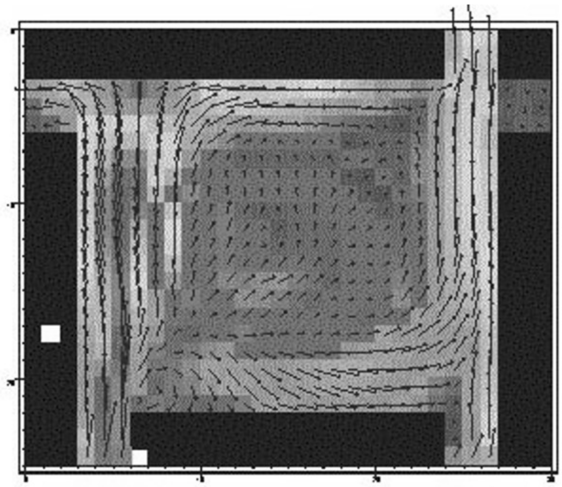

Figure 5: Wind patterns around Bedford Square, in central London based on simulations and measurements.

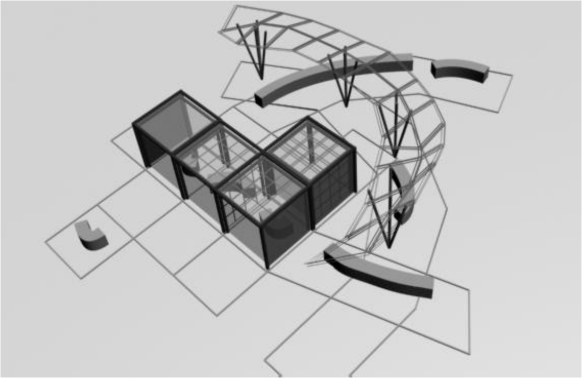

Figure 6: Proposals for an “urban living room” to be sited outside the AA School on the pavement of Bedford Square, London.

2.4 Going Underground

The stations and passenger areas of the London Underground system provide some striking lessons for students of environmental design. In the first instance, the sheltering provided by the surrounding earth has a stabilising influence on tunnel and platform temperatures. However, high daily heat gains from train motion and passenger body heat (average of some three million passenger journeys per day) result in platform temperatures that are well above the *undisturbed* ground temperature at tunnel depths (normally around 10°C in London). This can be seen from the spot readings of air temperatures taken by one of the project teams three times a day at various points of a London Underground station, Fig. 7. Note that although the outdoor air temperature near the station varied in the range of 10-15°C, the air

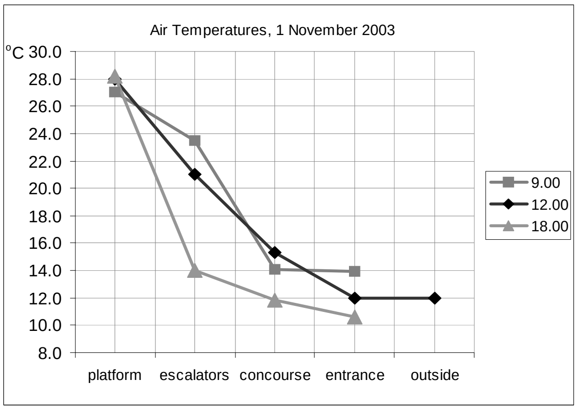

Figure 7: Spot measurements in different parts of a London Underground station.

temperature on the underground platform remained stable in the vicinity of 28°C. Clearly, this is too high for passengers coming from the outside with winter outdoor clothing. Uncomfortably high temperatures persist for much of the year on most London Underground platforms.

Measurements taken at very short time intervals on the same platform a month later revealed very considerable instantaneous fluctuations of 4.0-5.0K in the air temperature, followed by much smaller fluctuations of 1.0-1.5K in surface temperature, Fig. 8. The measurements show extremely rapid rises in air temperature occurring within less than 60 seconds as trains approached followed by similarly rapid drop in temperature with train departure. The project team developed proposals for an adjustable internal lining of the tunnels to provide a variable amount of additional thermal capacity and heat dissipation, Fig. 9 (top) [13]. The corollary of this stage of the study was that by controlling the free heat gains comfortable temperatures could be achieved *naturally* all year round by earth-sheltering. The team proceeded to explore this lesson further by combining earth-sheltering with access to daylighting, natural ventilation and a garden roof landscape as part of a greener urban architecture, Fig. 9 (bottom).

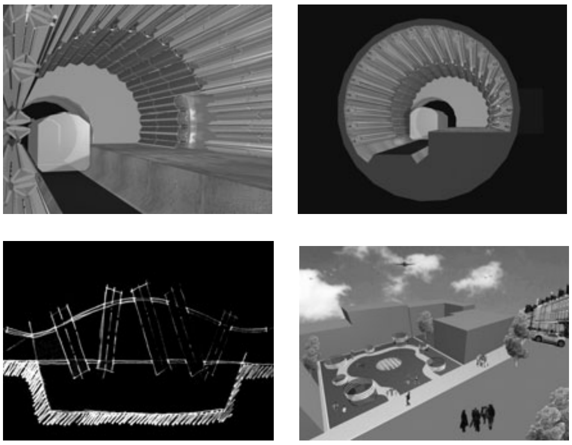

Figure 9: Proposals for an internal skin to increase heat storage and heat dissipation (top) and concept for earth-sheltered urban buildings (above).

2.5 Folds and clothing

Adjustments to clothing are generally the most direct and immediate mechanism of adaptive thermal comfort on a daily as well as seasonal basis. Colour, type of fabric, tightness and layering are common clothing factors or mechanisms over which individuals have a choice that can influence their sensation of thermal comfort. Measurements undertaken by one of the project teams suggested that *folding* may represent an additional or alternative such mechanism, Fig. 10. Folds can influence the thermal resistance and exposure of clothing thus increasing or decreasing heat loss rate.

The folding or unfolding of a fabric can act as the adaptive mechanism. Having identified variations in the rates of heat loss of different parts of the human body, as well as the variations produced by different

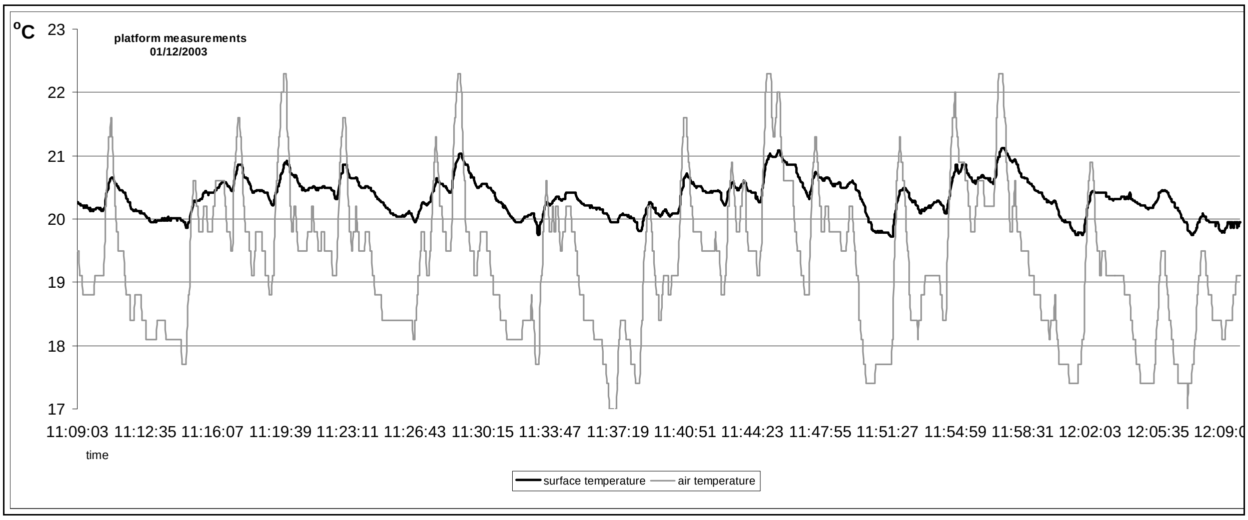

Figure 8: Surface and air temperature readings taken on train platform at short intervals over the course of one hour showing fluctuations caused by arrival and departure of trains and passengers.

body shapes, the team embarked on an extensive investigation of the environmental characteristics of different types of folds and their potential association with different parts of the body, Fig. 11 [15].

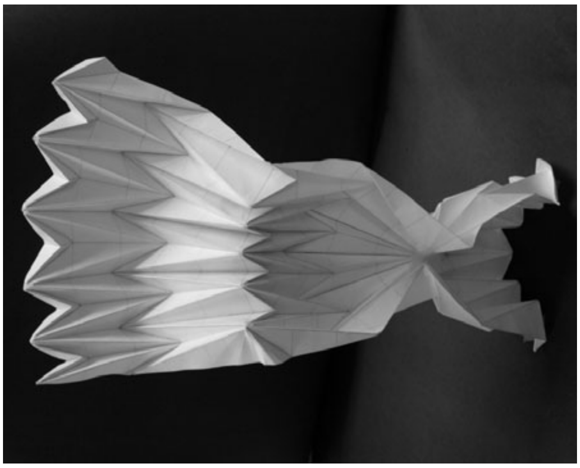

Figure 10: Folds

Figure 11: Testing folds

3 A PORTABLE BIOCLIMATIC SHELTER

In a hands-on follow-up to the theme of Adaptive Skins, the entire Masters group collaborated on the design and construction of a prototypical shelter for use by archaeologists carrying out work in sunny summer conditions, Figs. 12-14. The structure is made of timber, hemp rope and cotton sailcloth. Its components were constructed by the group at the AA School's Hooke Park and Chings Yard workshops. This work was undertaken as a contribution to one of this year's study trips that took the group to the island of Santorini in Greece. The components were transported as hand luggage and assembled in less than a day in April 2004 on a site provided by the municipality of the town of Oia on the northern corner of the island. The form of the roof is derived from solar geometry. The fabric cover is set to obscure segments of the sunpath so as to prevent direct solar radiation from reaching the work area during summertime in geographic latitudes below 40N. The structure is open to air movement and diffuse illumination from the northern half of the skydome.

The saddle shape of the tensile fabric works like an inverted wing; strong winds tend to push the structure into the ground. The mesh skirt hanging from the north side cantilever blocks low level north winds and blowing dust that can be quite disruptive around the Aegean if left uncontrolled. The fabric can be soaked with water, providing evaporative cooling underneath. The structure can be fitted with thin film photovoltaics, providing power for computers and other devices used by archaeologists in the field.

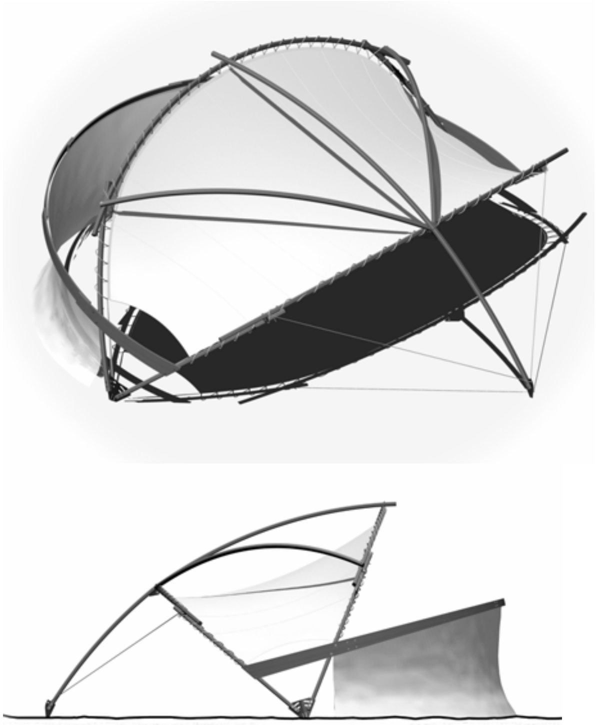

Figure 12: Axonometric view from south-west (top) and eastern elevation (above).

Figure 13: The bioclimatic shelter as erected on Santorini in April 2004 being shown to locals and visiting students from two other universities.

4 LESSONS AND CONCLUSIONS

In our teaching programme each year is some sort of experiment. What the teaching programme will cover, how and when this will be presented and how and

Figure 14: Images showing aspects of the process of design and construction of the bioclimatic shelter

where it will be used are important questions. Recent architectural graduates have good skills in the use of graphics software and three-dimensional modelling and simulation. However, the skills required for *numerical* simulation, and in particular the ability to interpret results, understand the processes underlying such results and identify the physical entities or operations that should follow are not available from previous experience and can take a while to develop. Although thermal and lighting simulation software has become much easier to use for the architect there are still some usability issues and important limitations persist especially with respect to airflow simulation, integration of lighting and thermal analysis, comfort studies and urban microclimate analysis. Our project teams' choice to focus on outdoor urban spaces from their first project of the year presented a serious challenge. This was in addition to the perennial problem that architectural students bring upon themselves by aiming to produce meaningful design proposals using just acquired knowledge and tools that are known to require years of incubation and practice. Yet unless the knowledge and tools are put to test straight away in a design or real life environment, they may never be used. And this remains one of our ongoing challenges in environmental design education and practice.

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