SUSTAINABLE DESIGN IN ARCHITECTURE

SIMOS YANNAS


Photo by Hara Yannas, august 2005

Diretor do programa de pós-graduação Environment and Energy da Architecture Association Graduate School desde 1979 e coordenador acadêmico do programa de doutorado da AA Graduate School desde 2004. Estudou arquitetura na Ecole Polytechnique em Lausanne, na National Technical University, em Atenas, graduando-se na Architectural Association School of Architecture, em Londres. Exerceu a prática arquitetônica de projeto na Grécia antes de voltar a Londres, onde vem se dedicando ao ensino e à pesquisa na AA Graduate School. Foi orientador de mais de 100 dissertações de mestrado e 25 doutorados, com alunos de todas as partes do mundo, incluindo vários brasileiros. Seu doutorado tratou do tema da eficiência energética em habitações no Reino Unido, seguido de uma série de pesquisas em questões relacionadas à tecnologia e à arquitetura sustentável, desenvolvida em parcerias com instituições de excelência do cenário internacional.

Desde os finais dos anos 70, Simos Yannas tem ministrado palestras em todo o mundo, totalizando visitas a mais de 30 instituições. É autor de mais de 100 publicações, incluindo artigos científicos, artigos para revistas especializadas e livros. De suas diversas publicações traduzias em mais de 12 línguas, merecem destaque os dois volumes do livro *Solar energy and housing design*, de 1994, e suas duas últimas obras, das quais é co-autor: *Roof cooling techniques – A design handbook*, publicada em Londres e Nova York em 2005, realizada com apoio da União Européia, e *Em busca de uma arquitetura sustentável para os trópicos*, publicada no Rio de Janeiro em 2004, com apoio da Capes e do CNPq. Recebeu o prêmio PLEA (Passive Low Energy Architecture) International Achievement Award, em 2001.

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Apresentação

A Architectural Association School of Architecture de Londres, com 155 anos de existência, consolidou-se como um centro de excelência de reconhecido valor para estudar e refletir sobre questões da arquitetura e do urbanismo. Primando pela experimentação, diversidade e discussão teórica, os cursos de graduação e pós-graduação da AA reúnem, atualmente, por volta de 500 estudantes, vindos de mais de 60 países. A variedade de culturas, especialidades e interesses, também presente no corpo de professores e pesquisadores de todos os cursos da escola, resulta em um ambiente fértil para o desenvolvimento intelectual e a inovação do projeto arquitetônico e urbano.

Como um fórum permanente de idéias e propostas, o ambiente acadêmico da AA é enriquecido por um extenso programa de palestras, exposições e seminários a respeito de temas relevantes da arquitetura e do urbanismo contemporâneos, abertos a estudantes da graduação, pós-graduação e visitantes. Quanto ao escopo e interesses da escola, estudos e investigações são direcionados tanto para a busca de respostas às necessidades e possibilidades presentes como para a antecipação de direções para a prática futura da arquitetura e do urbanismo.

No âmbito da pós-graduação, a AA oferece oito programas que se dividem em três grupos, de acordo com a natureza de suas atividades e propósitos. O primeiro desses grupos, com programas de mestrado, é formado por dois cursos que tratam de conservação, Building Conservation e Conservation: Landscape and Gardens, com conhecimento prático e teórico, e o segundo, com programas de mestrado e doutorado, é formado pelos cursos: Environment and Energy, Histories and Theories e Housing and Urbanism, os quais, na opção de mestrado, combinam *workshops*, exercícios de projeto e trabalhos científicos analíticos. O terceiro grupo, como no primeiro caso, oferece exclusivamente programas de mestrado, dedica-se à investigação do projeto de arquitetura, sendo formado por três cursos: Design Research Lab (DRL), Emergent Technologies + Design e Landscape Urbanism. Neste último caso, por serem fundamentalmente programas de estúdio, o foco é o projeto de arquitetura como um instrumento de pesquisa e análise.

Por se constituir essencialmente em uma instituição, formalmente desvinculada de qualquer universidade, todos os diplomas da AA Graduate School são validados pela Open University Research School.

Vale destacar que nesse contexto de experimentações e discussões teóricas que é a AA, uma característica marcante dos cursos referentes diretamente ao projeto arquitetônico, e também do Environment and Energy, é o uso de ferramentas avançadas de simulação computacional, certamente trazendo uma contribuição significativa para a vanguarda da metodologia de projeto.

Neste depoimento, o professor doutor Simos Yannas, diretor do programa de pós-graduação Environment and Energy, desde 1979, discorre sobre os objetivos e o processo de ensino e pesquisa do curso, destacando seu caráter projetual, sua internacionalidade e uma visão crítica sobre questões atuais da arquitetura de baixo impacto ambiental. No último ano acadêmico o programa de mestrado do Environment and Energy, anteriormente reconhecido como Master of Arts, foi reestruturado para Master of Science (MSc) e Master of Architecture (MArch), de acordo com o perfil das atividades desenvolvidas pelo aluno em sua conclusão de curso. Nesse sentido, para o MSc é realizado um trabalho de investigação científica (analítica), enquanto o MArch implica em um exercício de projeto de arquitetura embasado pelo conteúdo específico do curso.

Dentre outras razões, o desdobramento do curso em MSc e MArch tem o objetivo de responder a uma demanda crescente de profissionais de projeto pelo conhecimento de conforto ambiental e eficiência energética na prática arquitetônica, o que certamente vem ao encontro da natureza da AA, que é, primordialmente, a experimentação em projeto. Paralelamente, a pesquisa científica no curso tem reforçado o propósito de contribuir para o desenvolvimento de soluções arquitetônicas e de projeto urbano, visando ao conforto ambiental, à eficiência energética e ao menor impacto ambiental do ambiente construído.

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Professora doutora do Departamento de Tecnologia da Arquitetura da FAUUSP, arquiteta e urbanista pela Faculdade de Arquitetura e Urbanismo da Universidade Federal do Rio de Janeiro em 1994 e mestre pela Architectural Association Graduate School, Londres, no programa Meio Ambiente e Energia (Environment and Energy) em 1997. Pesquisadora visitante no programa de pós-graduação da Architectural Association Graduate School em 2001/2002.

Introduction

The Architectural Association School of Architecture Environment & Energy Studies Programme (AA E+E) is devoted to the application of sustainable environmental design at the level of the city and the individual building. AA E+E was started in 1974 with a one-year postgraduate Diploma course and two-year Honours Diploma. In 1995 the taught programme was validated to award a Master of Art (MA) degree and in 2005 the MA was replaced with a 12-month Master of Science (MSc) and a 16-month Master of Architecture (MArch) in Sustainable Environmental Design. These changes follow the AA E+E programme's expansion in design content and technical capabilities, as well as underlining the importance given to sustainable environmental design internationally within architecture, engineering and urbanism. Since the late 1970's the programme's development has benefitted from funded research and from its parallel research degree options leading to Master of Philosophy (MPhil) and Doctor of Philosophy (PhD) research degrees which continue today. AA E+E also contributes to undergraduate teaching with taught courses, project tutorials, training in environmental software and participation in the AA School's research cluster on ecologies, environment and sustainability.

AA E+E's main research object is the relationship between architectural form, materiality and environmental performance and the role played by climatic conditions, building programme and other interacting contextual parameters. The dynamics of this relationship are now underpinned by a vast, cross-disciplinary knowledge base of increasing technical and computational complexity. As a result the pedagogy of sustainable design is in itself a major research project. The technical knowledge and design skills provided by the AA E+E Masters Programme in Sustainable Environmental Design question both the premises and the products of current architectural practice highlighting alternative programmatic agendas and research outcomes. The taught programme reviews theories and practice of sustainable design, defines criteria for an environmental architecture, presents case studies by leading practitioners, and provides training in the use of computational tools to inform design decisions. Project workshops combine design research with environmental analysis and innovative building experiments.

Over the last three academic years the projects undertaken as part of our Masters programme have aimed to qualify the environmental attributes and performance of built form in a number of specific ways. In 2002-03 we explored designs for a *performative* space in projects culminating with the construction of a structure for a village school in Ghana followed by design proposals for mixed-use development in central London. In 2003-04 we focused on the *adaptive* nature of human thermal comfort and its implications for microclimatic interventions in the urban fabric. This inspired projects that ranged from kinetic urban landscapes and climatic pavilions to designs for new forms of street clothing. In a hands-on follow-up the entire Masters group worked on the design, fabrication and in-situ testing of a prototypical shelter on the Aegean island of Santorini, Greece. In 2004-05 we took these preoccupations a step further through an investigation of morphogenetic attributes of local climate and ecology in six different climatic regions. Following from these projects, mostly undertaken in the form of teamwork, dissertation projects are carried out individually. Over the years these have encompassed research topics dealing with most main building types, environmental typologies and climatic zones in some fifty different countries.

One of the key lessons over these years has been that although our field keeps getting reinvented, it never stops changing. An environmentally-responsive architecture is not a fixed ideal, but an evolving concept that should be redefined and reassessed with each new project. We need to move beyond the technical fixes perpetrated by much of current practice and extend our architectural vocabularies so as to express the temporality of natural and operational cycles in more creative ways. Education should take a lead in the evolution of this architecture. Our taught programme deals extensively with the following three key issues:

– the *cognitive domains* that inform our designs

– the *environmental performance* targets to aim at

– the environmental attributes of *the urban context* we are dealing with.

COGNITIVE DOMAINS

Interactions between buildings and the natural or manmade microclimates that surround them tend to vary across space, as well as over time, affecting indoor conditions in ways that are often counter-intuitive. Predicting the outcome of such interactions and mitigating their effects for the purpose of achieving thermal and visual comfort for human activity in and around buildings, requires specialist knowledge and tools. Such knowledge and tools derive from three main sources. *First*, a good theoretical grounding is essential to provide designers with the ability to conceive ways in which to translate environmental attributes into architectural form and features. This type of knowledge is acquired by undertaking specialist studies during or after an architectural or engineering degree. *Second*, we need empirical knowledge on how well different techniques have worked in practice, and the extent to which their performance has satisfied environmental design criteria that were set at the design stage. This type of knowledge is acquired by direct observations and measurements after spaces have been occupied and used. *Third*, we need analytic tools that can provide reliable predictions of the likely outcome of our design choices so as to inform our decision-making and fine tune the final designs. This type of knowledge is acquired by following specialist training in the use of and application of environmental simulation software. Today few practising architects and students of architecture have specific knowledge in any of these three cognitive domains. Yet to face our current environmental challenge we need proficiency in all three.

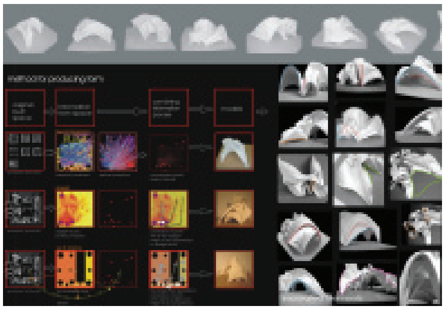
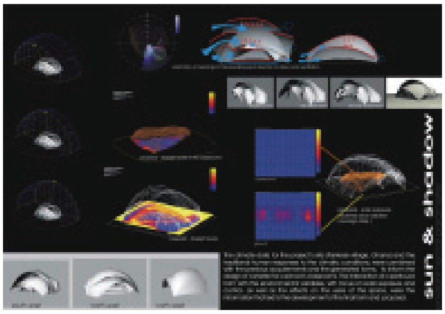
PERFORMANCE

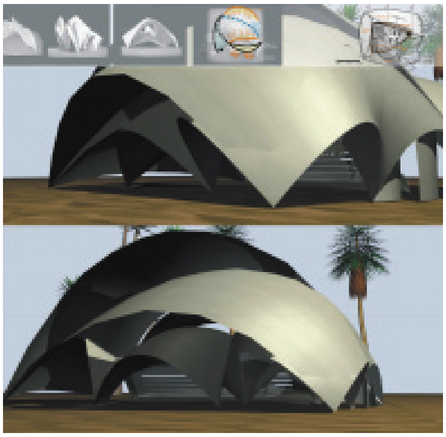
There are some critical questions we have to ask repeatedly. For example, what should an environmentally-responsive architecture be capable of? Is it feasible to eliminate all conventional HVAC equipment and carbon emission (brazilian engineers are likely to dispute this, but what if their consultancy fees increased in line with improvements to building performance rather than with the size of the air conditioning plant)? What kind of environmental conditions should we seek to attain in different climates and building types? Such issues lead to further questioning on how any given performance is to be achieved. Most of the answers to such questions should change each time we ask the questions. Despite of heavy investment in mechanical plant and artificial lighting and very high operational energy costs, few contemporary buildings seem to satisfy occupant thermal and visual comfort requirements. Study of the mechanisms of adaptive comfort has provided design insights for different building programmes and climates. In some european countries a trend toward zero, or even negative, carbon emission has begun with some recently built schemes. Similar trends can be foreseen for other building types and climatic regions. Near zero carbon emission from space heating and cooling is feasible and should be a performance target for new buildings in most climatic regions. With conventional mechanical and electrical engineering representing a very large proportion of the capital costs of non-residential buildings, this can release huge amounts of capital that can be invested in improving architectural and environmental quality, as well as achieving thermal and visual comfort.

THE URBAN ENVIRONMENT

Field studies 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 both fosters and accommodates distinct microclimatic niches for which we have little quantitative data with which

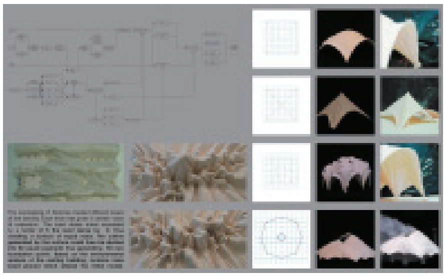
Performative Space
Santiago Aguerrebere, Angeliki Chatzidimitriou, James Erickson, Alexander Herrera-Rojas, 2003



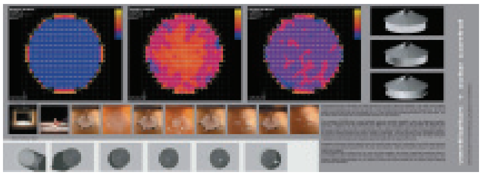
Performative Space
School shelter at Pankese village, Ghana, 2003

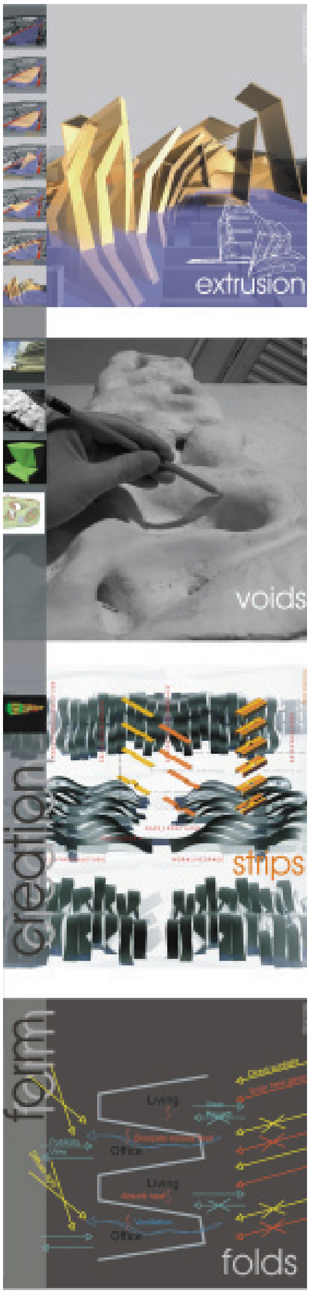
In the City
Illustrations from *In the city,* project by 2002-03 MA group

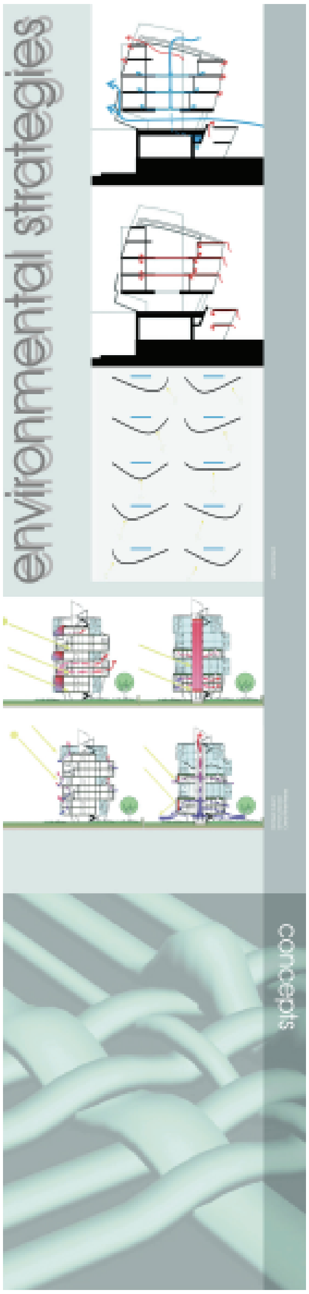


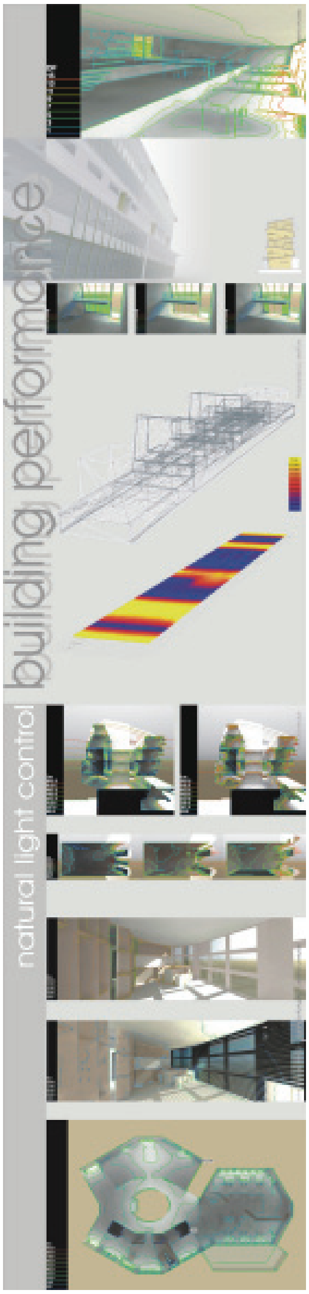
Performative Space

Werner Gaiser, Annie Cheung, Autumn Peterson, 2003









to inform design. These microclimates are partly an outcome of the built density and geometry of urban locations. Both built density and geometry strongly affect solar exposure and air flow within the fabric of the city. Differences in sun and wind patterns 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, plant growth, and heat dissipation and these in turn contribute to the differentiation and characterization of the microclimate. Urban microclimatic variability is also the result of anthropogenic sources located inside, as well as outside, buildings. Such anthropogenic sources contribute to the urban heat island effect and are commonly also associated with carbon emission and air pollution. On the other hand, it is now also clear that a process of ecological regeneration can 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. And hence some more questions. How can we characterize the microclimatic profile of an urban 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?

These then are key issues for our teaching programme in sustainable environmental design at the AA School of Architecture. And such are the questions providing us with starting points for research and design projects. In our Masters programme students will typically work on two to four short projects in the first term (10-12 weeks) of the year, a longer team-based design project in the second term, and their main dissertation projects in the third and fourth terms. Four of these first and second term projects that were undertaken in the period 2003-05 are illustrated in the following pages.

PROJECTS

The following projects are illustrated here with a selection of material from some of the participating student teams.

– Performative Space 2002-03 (Term 1)
– In the City 2002-03 (Term 2)
– Adaptive Microclimates 2003-04 (Terms 1 & 2)
– Generative Skin 2004-05 (Term 2)

Three built projects which were undertaken as hands-on extensions with the participation of the entire masters group are also shown:

– School shelter at Pankese village, Ghana, 2003
– Shelter for archaeologists, April 2004
– Heliotropic urban bench, May 2005

PERFORMATIVE SPACE

The project started with an analysis of some well known contemporary buildings in different countries. Critical information derived from these studies became an input for the investigation of new architectural forms applying exploratory modelling techniques. Following a stage that used physical models and tested design hypothesis with measurements, heliodon and wind tunnel, work on the project continued using the digital models introduced in the taught programme in order to assess the relationship between form and performance in more detail. As students' knowledge and use of tools improved the project's brief was directed toward the design of a new built structure for a village school in Africa. In early february 2003 design proposals developed till then by different student teams were merged and, in the course of a ten-day study trip to Ghana, a timber structure was erected by a group of undergraduate (2nd and 3rd year) and postgraduate students at Pankese village outside Accra (latitude 5°N). The illustrations are from two of the project teams.

IN THE CITY

The site, Goodsyard, in London's Bishopsgate area is a redundant 19th century railway interchange adjacent to the city's financial centre. The project brief called for mixed-use development combining dwelling units with workspaces and shops. New buildings on site were expected to be close to self-sustaining. Project teams were required to start the project by studying the changing trends in household composition and work-home relationships taking place in London recently. The site's elongated form and elevation six metres above street level, over a network of victorian brick arches, offered excellent conditions for using sun and wind. London (latitude 51°28'N) has a temperate climate with mean monthly temperatures ranging between 4.2°C in January (coolest month) and 17.5°C in July (warmest month). A selection of diagrams and drawings combining the projects of several student teams are shown here to illustrate the approach, generative concepts and representational techniques used on the project.

ADAPTIVE MICROCLIMATES

The first stage of this project involved observations and measurements in outdoor spaces around central London. The objective at this stage was to investigate the mechanisms underlying different microclimates in the urban environment. The variability of London weather and the effect that solar radiation and wind patterns have on outdoor thermal comfort 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.

Adaptive 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. 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 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.

Outdoor Furniture

Complementary options were explored by a second team with proposals for outdoor elements and furniture for streets and parks.

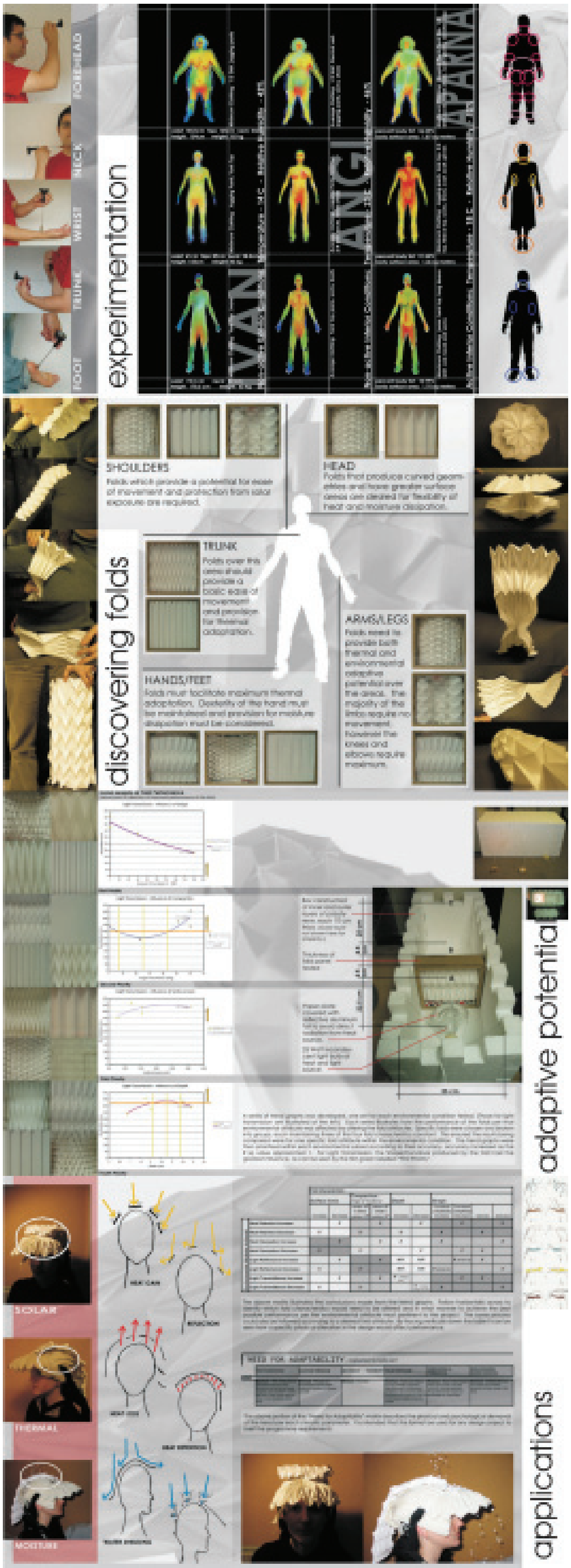
Adaptive Landscapes

Parts of this site on the south side of the Tate Modern Gallery in South London have good solar access, which is a very valuable commodity in a high latitude urban environment. In London wind patterns are mostly disruptive for pedestrians. However, air temperatures are mostly moderate, and thus protection from wind and rain are deciding factors for providing comfort in outdoor microclimates. The focus of the proposals is the creation of a dynamic landscape of variable surface properties conceived as consisting of three complementary layers. A landform layer of stabilized soil is planned to sit on an hexagonal grid designed to regulate upward or downward movement with the aim of providing a wind shadow or improving solar access, thus aiming to improve outdoor thermal comfort on site in response to weather conditions. 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. 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. Various activity layers can then be inserted into the site combining architectural elements and outdoor furniture with complementary climatic properties.

Climatic Pavilions

Observations of microclimatic effects around London squares and other open spaces led this team to design these small pavilion-like shelters

Adaptive Microclimates
Adaptive Clothing
Ivan Kaye, Aparna Maladkar, Angela Rivera, 2004



SHOULDERS
Folds which provide a potential for ease of movement and protection from solar exposure are required.

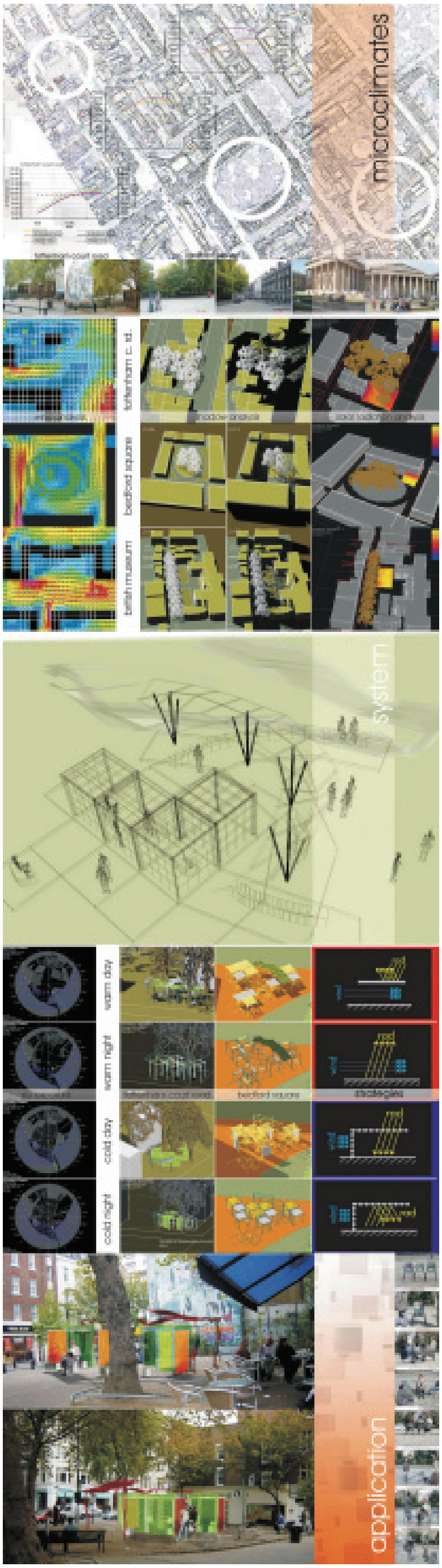
HEAD
Folds that produce curved geometries and have greater surface areas are desired for flexibility of heat and moisture dissipation.

TRUNK
Folds over this area should provide a basic ease of movement and provision for thermal adaptation.

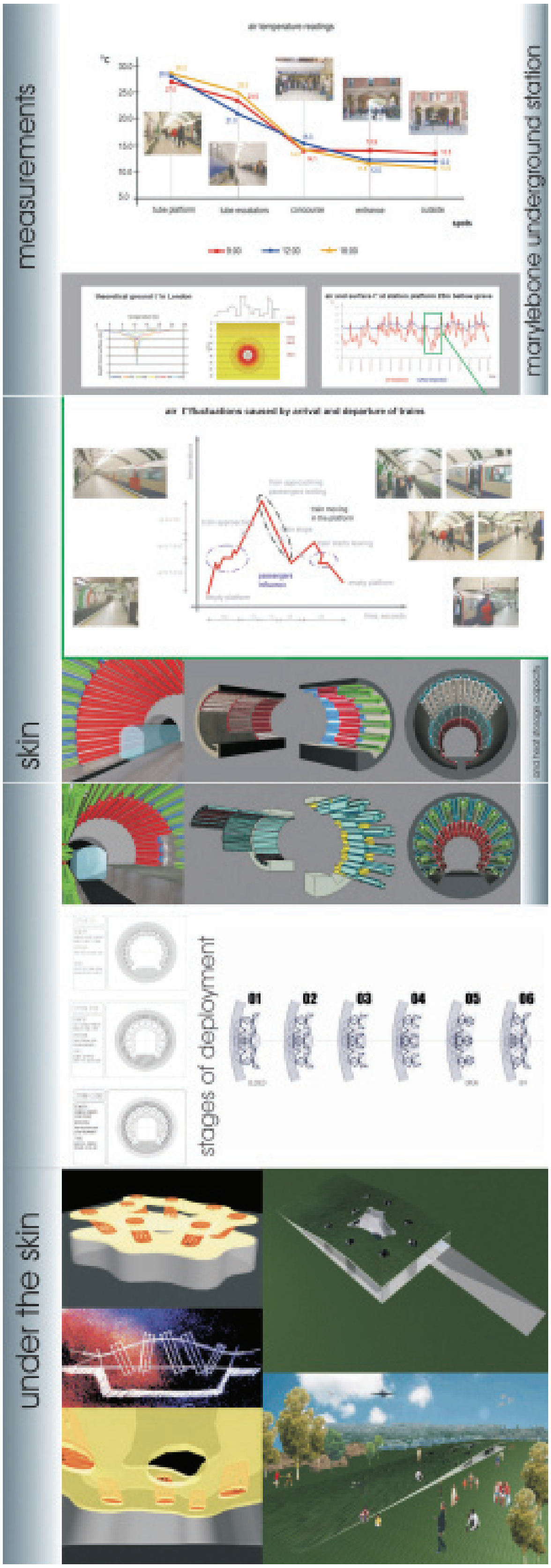
HANDS/FEET
Folds must facilitate maximum thermal adaptation. Dexterity of the hand must be maintained and provision for moisture dissipation must be considered.

ARMS/LEGS
Folds need to provide both thermal and environmental adaptive potential over the areas. The majority of the limbs require no movement, however the knees and elbows require maximum.

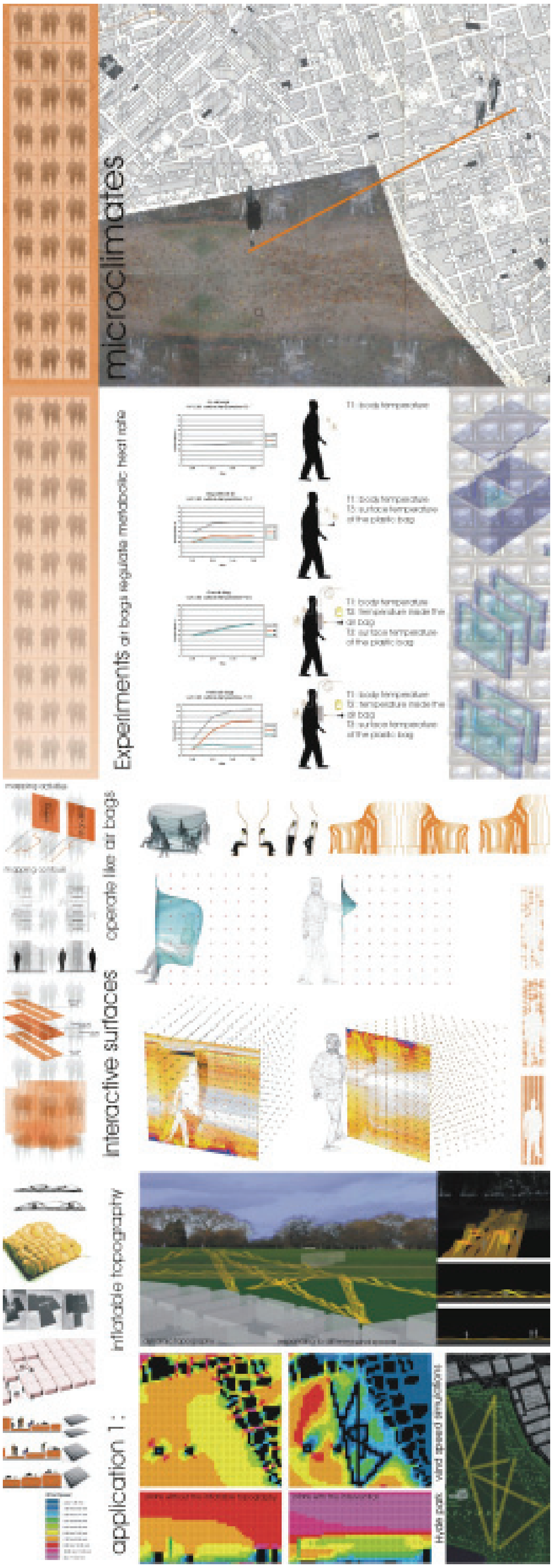
Adaptive Microclimates
Adaptive Landscapes
Fotini-Lida Kalamatianou, Celina Martinez, Kevin Pratt, 2004



Adaptive Microclimates
Climatic Pavilions
Gustavo Brunelli, Barbara Kreitmayer, Jiayuan Zou, 2004



Adaptive Microclimates
Going Underground
Carlos Estrada, Evangelia Filippopoulou, Monica Marcondes, 2004



for use by passers-by or bus passengers conceived as composed of movable elements providing the adaptive mechanisms.

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 can be observed to have a stabilising influence on tunnel and platform temperatures. This is as expected from earth-sheltering. However, the high amounts of daily heat generation from the motion of trains and the body heat of passengers (from some three million passenger journeys per day), raise the temperatures on station platforms well above the *undisturbed* ground temperature at tunnel depths (which would have been around 10°C in London but is currently closer to 18°C). As a result although the outdoor air temperature near the station varied in the range of 10-15°C (the measurements were taken in november 2003), the air temperature on the underground platform remained stable in the vicinity of 28°C. Clearly, this is far too high for passengers coming from the outside wearing winter outdoor clothing. Nevertheless uncomfortably high temperatures persist for much of the year on most London Underground platforms. The project team developed proposals for adjustable internal linings of the tunnels to provide a variable amount of additional thermal capacity and heat dissipation. The objective of this part of the study was to control the free heat gains so as to achieve comfortable temperatures *naturally* all year round. 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.

GENERATIVE SKIN

The Generative Skin Project was a one-term design brief introduced in january 2005. *Generative* refers to an ability to produce or originate. On this project the word assumed two distinct, but complementary, meanings: the skin as generator of built form and “passive” climatic modulator; the skin as “active” collector, store, distributor or dissipator of energy (Figure 1). The building programme was for a mixed-use development with a degree of freedom in defining use as a function of contextual parameters. Six project sites were selected in different climatic regions in order to explore the morphogenetic attributes of local climate and ecology. The project was undertaken in teams of two or three. The six schemes were developed for equatorial climate (Manaus, Brazil 3°S latitude and Karon Beach, Phuket Island, Thailand 8°N); Tropical (Dhaka, Bangladesh 23.5°N); Arid (Tempe, Arizona 33°N); Mediterranean (San Francisco, California 37.5°N); and Alpine (Innsbruck, Austria 47°N). Four of these are illsutrated here.

Equatorial

The concept for the building evolved from the need to provide shade and air movement in this tropical wet climate with little seasonal variation. The building is raised on pilotis. The skin combines several functions that allow control of relative humidity as well as shading and air permeability.

Arid

Climate analysis and computer simulations suggested passive systems using the ground as heat sink and evaporative cooling in periods of high outdoor temperature and low relative humidity. The graphs illustrate the shift towards thermal comfort that can be achieved as a function of ground cooling. The solar chimneys on the southern side of the building draw the earth-cooled air into the occupied spaces.

Mediterranean

A public plaza and market form part of the building programme in this proposal inspired by the seaside waveform.

Alpine

The design brief chosen by this team called for an architecture centre as extension to the local university campus. Outdoor air temperatures in the region are below comfort levels for up to nine months. The generative concept for this cool climate is one of layering and buffering.

Learning by doing

SHELTER FOR ARCHAEOLOGISTS

In a hands-on follow-up to the theme of Adaptive Microclimates, the entire 2004-04 Masters group collaborated on the design, fabrication, erection and testing of a prototypical shelter for use by archaeologists carrying out work in sunny summer conditions. The structure is made of timber, hemp rope and cotton sailcloth. Its components were fabricated by the students 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 a couple of hours in April 2004 on a site provided by the mayor of Oia, a town 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 40ºN. 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.

A HELIOTROPIC URBAN BENCH

On a return study trip to Santorini in May 2005 to take part in an international conference on passive cooling in the built environment, the 2004-05 Masters group collaborated in the design and construction of a small structure that was transported, assembled and tested there. The structure was conceived as a piece of urban furniture that can be shaded and ventilated by moving the constituent elements. The moving parts of the structure allow users to vary the proportion of the sky dome that is obstructed or exposed, and to expand or contract openings for air movement. The components were fabricated of laminated timber at the AA School's Hooke Park and Chings Yard workshops and transported to Santorini as hand luggage. The structure was assembled and exhibited, first at the PALENC 2005 international conference in the town of Fira and subsequently on the main square of Oia on the north of the island. Each reassembly of the structure provided useful insights on its environmental performance, usability and adaptability. In each case the group was able to make adjustments to improve performance and usability. The structure was further modified for the end of year exhibition at the AA School and is due to travel back to Greece for an exhibition organized by the Institute of Greek Architects in Patras later in 2006.

Conclusion

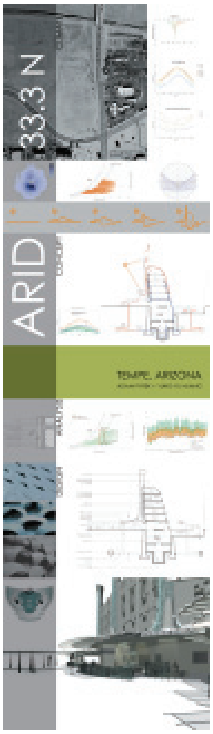
For our teaching programme each year is an experiment and a continuing adventure. Given the single calendar year span of the MA programmes at the AA School the amount of time available to each of the projects described above was limited to some 10-12 weeks. This has been a limiting constraint to the level of specificity and detailing that could be achieved. Working in teams partly compensates for the shortness in duration, and complementarity of skills within a team can be useful. The scheduling of projects in parallel to the formal programme of lectures and workshops helps students assimilate and apply the knowledge and tools provided by the taught courses. Jointly they provide the basic training on which is built the more in-depth research that characterizes the work for the dissertation projects which occupy the second half of our Masters Programmes.

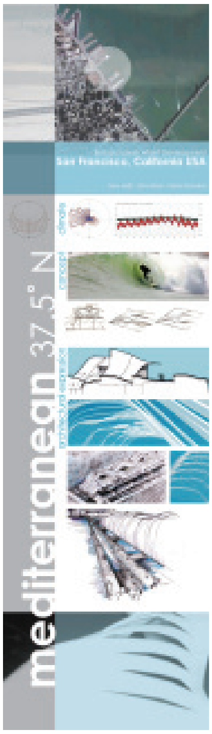
Generative Skin
Equatorial
Monica Goncalves, James Kraus, 2005

Arid
Adam Pyrek, Yung-Yu Huang, 2005

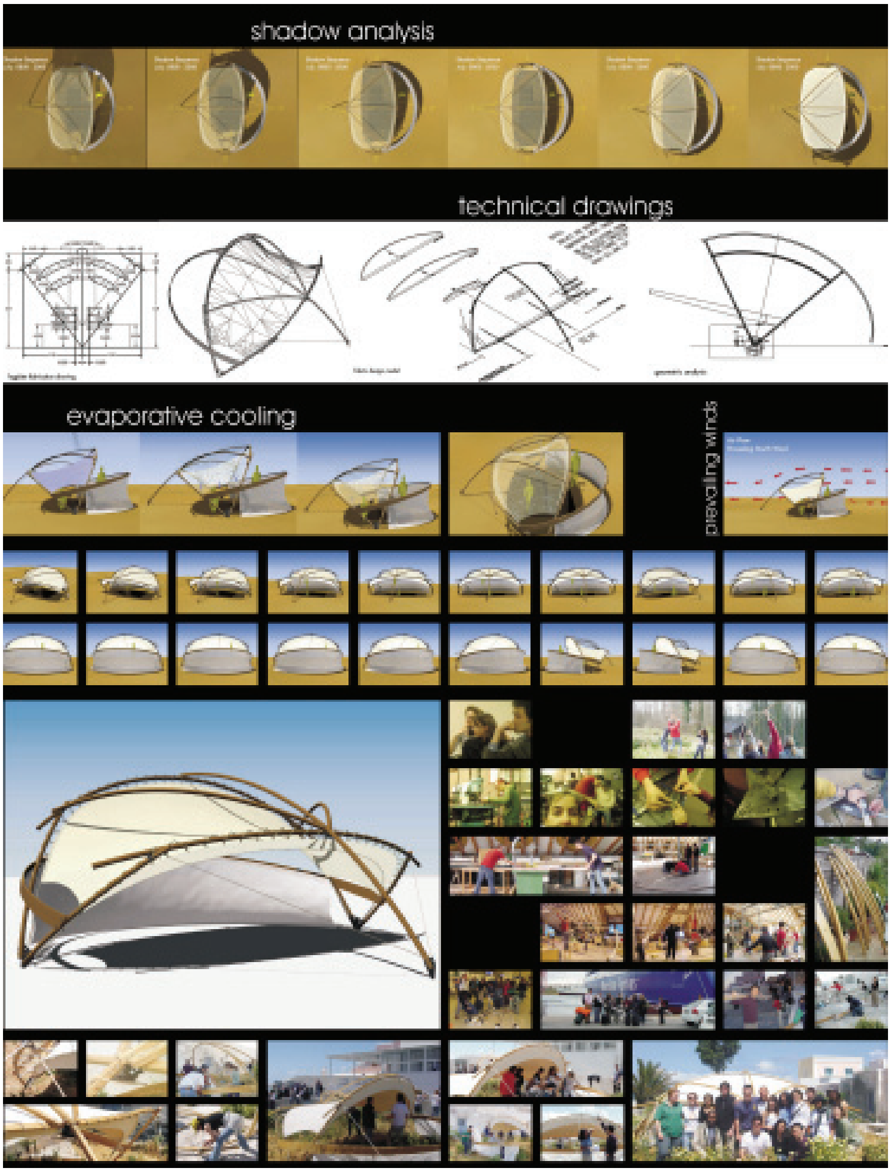
Mediterranean
Amy Holtz, Dino Rossi, Panos Gavalas, 2005

Alpine
Joy-Anne Fleming, Padma Mahadevan, 2005

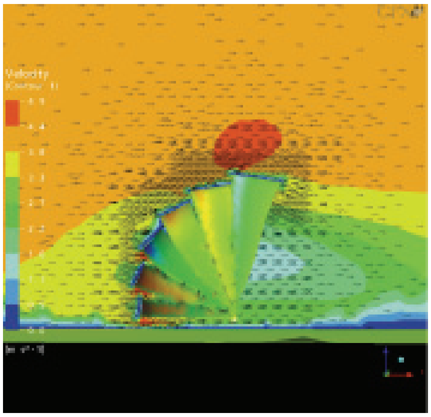




Shelter for Archaeologists



A Heliotropic Urban Bench



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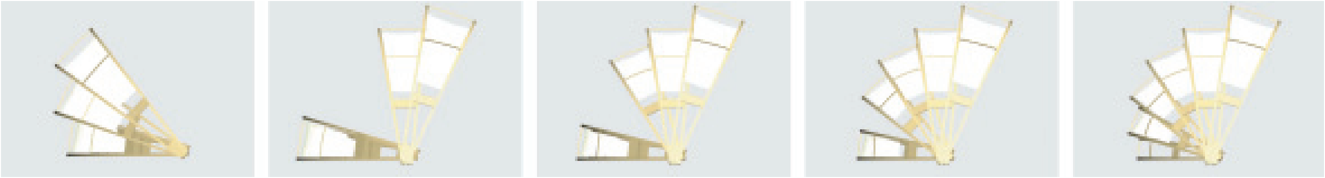
Heliobench Making

Heliobench Shadows



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Computer software introduced by our taught programme for use on the projects discussed above and on Masters dissertation projects includes: Meteonorm Global Meteorological Database for Solar Energy and Applied Climatology (Meteotest); Ecotect (Square One); TAS (EDSL Environmental Design Solutions Limited); CFX-5 Computational Fluid Dynamics Software (Ansys); ENVI-met (M. Bruse, University of Bochum).

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