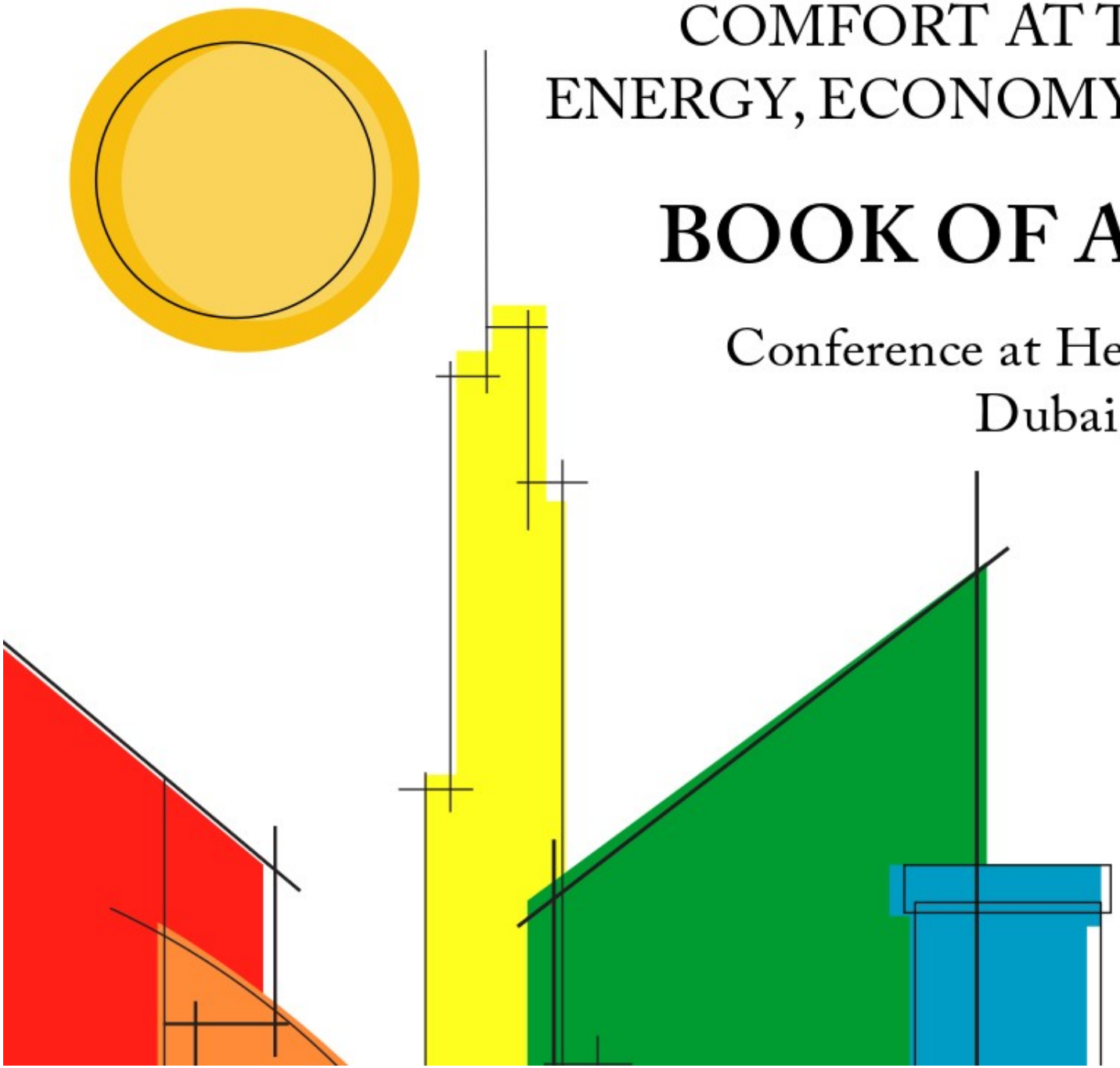

COMFORT AT THE EXTREMES: ENERGY, ECONOMY AND CLIMATE

BOOK OF ABSTRACTS

Conference at Heriot Watt University,
Dubai, 10-11th April 2019

Edited by Susan Roaf
and Will Finlayson

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SESSION 1 - Comfort & Health Limits

Chair: Susan Roaf

The Epidemiology of Health and Mortality at Extremes

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Epidemiological studies around the world have shown that heat exposure is an important public health issue, with heatwaves being responsible for more deaths than any other natural hazard. Historically, severe heatwaves in Europe, the United States, Russia and elsewhere, have been associated with reports of marked increases in mortality. Failure to maintain a level of thermal comfort can jeopardise the health of vulnerable members of the community, particularly the elderly, infirm, socially isolated or the very young.

Even in Australia, a country well known for its hot summer days, there is often an associated toll on human health in extreme heat, despite high rates of air conditioning. In winter, cold to very cold temperatures can also be experienced; however, much less attention is paid to maintaining warm living conditions in Australian homes. This, combined with badly designed houses, may be contributing factors to the number of deaths being higher in winter than in summer.

The aim of this paper is to discuss the temperature-mortality association, drawing on epidemiological evidence from a number of countries including Australia. The influence of the built environment on the association will be highlighted, together with suggestions for health and comfort at extremes in the future.

The limits to accepted indoor temperatures

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One characteristic of the adaptive approach to thermal comfort is that there is not a single 'comfortable' temperature but there are a wide range of temperatures which occur in indoor environments which can be acceptable to building occupants depending on their experience and circumstances. By looking at records of indoor temperatures from field survey a variety of climates and cultures this paper explores the limits of the acceptable indoor temperature range.

The Physiology of Comfort at the Extremes (Presentation only)

Wouter van Marken Lichtenbelt

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Research over the last decade has provided evidence of the impact of our thermal environment on human physiology and metabolic health. Importantly, it is known that upon regular exposure to cold and/or heat, adaptive processes occur. Our bodies have the ability to adapt to the specific thermal environment, and both our thermoregulatory physiology as well as thermal perception is improved. Moreover, environments just outside our thermal comfort zone have been shown to actually provide healthier conditions than a stable, uniform climate - just as exercise is often healthier when compared to comfortable, sedentary behaviour. This talk outlines some of this research and how the thermo-physiological responses interact with experiences of thermal comfort in everyday situations, and at more extreme temperatures.

SESSION 2 - Exceeding the Limits

Chair: Evangelia Topriska

Passive Survivability: Keeping Occupants Safe in an Age of Disruptions

Alex Wilson

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Passive survivability is defined as the ability of a building to maintain habitable conditions during an extended power outage or loss of heating fuel. There have been ongoing efforts in the United States to address this issue since Hurricane Katrina caused extended power outages in New Orleans in 2005. This paper reports on such efforts—focusing especially on the suite of pilot credits on Resilient Design in the U.S. Green Building Council's LEED Rating System. These recently updated and re-released (November 2018) pilot credits offer three compliance paths to demonstrate passive survivability. While these methodologies and metrics for passive survivability will almost certainly evolve in the coming years, they provide an important starting point for this critically important discussion.

Heatwave design response in Ahmadabad (Presentation only)

Rajan Rawal

Centre for Advanced Research in Building Science and Energy, CEPT University, Ahmedabad, India

In recent years, temperatures in Ahmedabad during the hot season have been broken on an almost annual basis, with the city experiencing extreme heat waves now on a yearly basis. For a city where some of its citizens live on the streets in informal communities, and where many cannot afford the high costs of air-conditioning, the mortality rates have been high during such events. The city has had to rapidly evolve new approaches to keeping its citizens thermally safe and in this presentation some of the related challenges and solutions are outlined in the hot dry season in north west India.

Thermal Adaptation of Buildings and People in Very Cold Climate of Nepal

Hom B. Rijal

Department of Restoration Ecology & Built Environment, Tokyo City University, Japan

A thermal comfort survey and a thermal investigation were conducted in traditional houses, during the winter in the Mustang district of Nepal. The thermal measurement was conducted in 9 houses for 7 days. The thermal comfort surveys were carried out over 4 days, gathering a total of 1,584 thermal sensations from 36 subjects. The results show that passive heating effects are found in houses with thick brick wall and mud roof, 2) residents are highly satisfied with the thermal condition of their houses, 3) the mean comfort temperature is 10.7 °C and 4) the comfort temperatures are different according to the thermal environment of the evaluated spaces. These findings reveal that people are well adapted to the thermal environment of traditional vernacular houses, as a result of which the comfort temperature is lower than the thermal comfort standard.

Refuge at the Extremes (Presentation only)

Sukumar Natarajan

Department of Architecture and Civil Engineering, University of Bath, UK

The provision of adequate shelter for refugees is becoming a globally pressing issue. Understandably, thermal conditions are not initially a primary concern when housing large number of individuals as a response to a humanitarian crisis. However, as the lifetime of camps is extended, these shelters move into a transitional state between temporary and permanent. Some studies have suggested the average lifetime of a transitional shelter is 17 years. The lack of a considered design approach that balances the urgency of installation against cost and comfort results in poor comfort and high levels of thermal stress. It is clear from our field surveys that shelter designs need to be sensitive to the background and cultures of camp residents if they are to be a humane and sustainable solution throughout their lifetime. This paper will explore some of the underlying design challenges for this field.

Characterization of Passive Cooling Systems for an Extreme Hot Humid Climate

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The consumption of energy for air conditioning in buildings has increased exponentially, exacerbated by the effects of Global Warming and Climate Change, this situation is particularly evident in hot climates. A promising alternative to mitigate this problem is the implementation of passive cooling systems, which can contribute to reduce energy consumption and at the same time provide hygrothermal comfort conditions for the building´s occupant. In particular, this situation is more severe in warm humid climates, where the implementation of indirect evaporative cooling systems is a promising approach. This investigation presents the results of a preliminary study conducted in experimental modules with five different systems, integrated on their top cover, compared with a control module. This investigation was carried out in the City of Mérida, Yucatán, Mexico, a climate with typical hot humid conditions. The methodology applied started with a calibration procedure of the equipment and data acquisition systems, followed by a pilot test conducted with a concurrent monitoring process in the six modules for ten days during a typical overheating period. The results indicated that the indoor air temperature in the best module reduced 5K relative to the maximum exterior temperature. This revealed a potential for energy savings by reducing the use of air conditioning, and whilst achieving hygrothermal comfort conditions for the occupants. These experiments will continue during other representative climatic, transitional and underheating periods.

Identity through Efficiency. (Re-)Discovering Passive Cooling Strategies as an Architectural Idiom for the Gulf Region

Nikolaus Knebel

German University of Technology in Oman (GUtech), Muscat, Oman, Department of Urban Planning and Architecture

The current architectural discourse in the Gulf runs in parallel streams. One is about creating identity through architecture and is focused on the appearance of buildings, as can be seen in many recently built public buildings that are designed with metaphoric images as expressive conveyors of a certain message. The other is about energy-efficiency and aims at enhancing the performance of buildings in the extreme local climate, which is demonstrated in the growing number of large commercial buildings that are audited and certified in energy-rating systems but are otherwise generic designs. While in the one discourse architectural form has a purely symbolic function it is negated in the other and overridden by technology. The problem is that these two discourses are disconnected. The scope of this paper is to show how efficiency and identity of buildings are connected through the issue of passive design strategies that can achieve both aims through architectural form. In order to analyse and communicate "proven solutions to recurring problems" about passive design strategies from the modern Gulf architecture, Alexander's Pattern Language method is applied. The result is a first collection of patterns that lays the basis for an architectural idiom that is place-specific and therefore energy-efficient and identity-generating at the same time.

Regular passive exposure to heat induces beneficial effects on cardio-metabolic health

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Regular exposure to elevated temperature has previously been suggested to have positive implications for metabolic and cardiovascular health. Two passive heat acclimation studies have been performed to assess the effect of repeated passive heat exposure on physiological parameters, cardiovascular and glucose metabolism, thermal comfort (TC) and sensation (TS).

Eleven young healthy men (YH, 24.6±2.7y, BMI:22.6±2.9kg/m2) and eleven middle-aged overweight men (MO, 65.7±4.9y, BMI:30.4±3.2kg/m2) participated in two separate studies. Both populations were acclimated to heat (YH:7d, ~33℃ and MO:10d, ~34℃) for 4-6h/d. Before and after acclimation, core and skin temperatures (Tcore and Tskin), heart rate, blood pressure, TC and TS were measured. Fasting plasma glucose (FPG) and insulin (FPI) samples were taken to indicate glucose metabolism and insulin response in MO only.

Tcore decreased in both groups post-PHA (YH:Δ-0.14±0.15℃, p=0.026; MO:Δ-0.19±0.26℃, p=0.036). Blood pressure decreased in both populations after heat acclimation, to a variable extent. Preliminary data suggests that FPG and FPI were lower post-acclimation. TS/TC remained unchanged. In conclusion, despite the relatively mild heat stimulus, passive heat acclimation induces distinct thermophysiological and cardiovascular adaptations in both populations, leading to increased resilience to heat. Glucose metabolism might improve in the middle-aged overweight population. Despite the physiological adaptations to heat, TS and TC remained unchanged.

Stress indexes and thermal comfort in structural timber school buildings during cold and warm seasons

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[1] Department of Architecture, College of Engineering, Technology, and Architecture (CETA), University of Hartford, West Hartford, Connecticut, USA

This study evaluates occupants' comfort and stress indexes in structural timber (CLT) school buildings in the North-eastern region of the USA during cold and warm seasons. The survey was considered from June-September 2017 and October 2017-February 2018 for the warm and cold seasons respectively. The buildings are rated and certified by the Leadership in Energy and Environmental Design (LEED), and they have won different sustainability awards due to their low carbon footprint. The study explored the monitoring of variables and occupants' comfort was assessed using the thermal comfort standards (CIBSE, BSEN15251, ASHRAE) for comparison. The mathematical models were applied to evaluate the stress indexes in the cold and warm seasons. The study showed the average outdoor temperatures of 4.8°C and 21.0°C in the cold and warm seasons in that order. The mean indoor temperatures of 20.2°C and 22.5°C were reported during the cold and warm seasons respectively. The average RH of 43.7% and 58.3% were measured in the cold and warm seasons. The average air velocity was within 0.1-0.2m/s. The overall mean CO_2 level was below 1000ppm, and it was within the acceptable range (350-1000ppm) for healthy and comfortable thermal environment. The classrooms and offices were warmer than the hall in the cold and warm seasons. The location of the hall, its orientation, large volume, frequent use of the doors and windows, as well as different activities carried out in the hall may contribute to the lower temperatures recorded in the space than the classrooms and offices. The outcomes of the mathematical models to evaluate the stress indexes show the WBGTs of 15.4°C and 19.1°C in the cold and warm seasons respectively. The UTCIs of 19.4°C and 22.6°C were computed for the cold and warm seasons. The study shows that building occupants are likely to be susceptible to cold stress and heat stress if external temperatures decrease or increase. The study recommends that further adaptive measures should be considered by the users to improve their comfort; thereby reducing their vulnerability to cold stress and warm stress in different seasons.

The impact of trees on passive survivability during extreme heat events in warm and humid regions

Ulrike Passe, Janette Thompson, Baskar Ganapathysubramanian, Boshun Gao, Breanna Marmur

Iowa State University

Communities are increasingly affected by excessive heat. The likelihood of extreme heat events is predicted to increase in the Midwest region of the United States. By mid-century (2036–2065), one year out of 10 is projected to have a 5-day period that is 13°F warmer than a comparable earlier period (1976–2005). The frequency of high humidity/dew point days ("extra moist tropical air mass days," MT++ synoptic climate classification system) has also increased significantly during a similar period (1975–2010) and between 2010 and 2014 included 8 of 26 heat events. This impact is exacerbated by the fact that many residences in low-income neighbourhoods in the US do not have central air-conditioning systems (e.g., up to 50% of low-income homes in Polk County, the location of our study in the US Midwest). Modifications to urban landscapes by the addition of trees can modify temperatures in the nearby environment, which is important for reducing summer heat loads on building surfaces. Trees can reduce energy use and improve indoor and outdoor comfort for cooling in summer by casting shade and providing evapotranspirational (ET) cooling. This paper presents a methodology to combine spatially explicit three-dimensional tree morphology and estimates of ET rates with building location and wall characteristic data to test their relative contribution to building energy consumption. Based on a comprehensive tree inventory for our Midwestern study neighbourhood, tree morphology and building data have been integrated in a three-dimensional array in the "Urban Modeling Interface" (umi) to estimate cooling due to interception of sunlight. We then perform a series of parametric computational fluid dynamics (CFD) studies to simulate ET cooling for various tree morphologies and relative locations to walls. We resolve conventional mesh generation challenges associated with CFD by introducing a novel, immersed boundary framework based on adaptive octree meshes. This approach can seamlessly include trees and buildings at arbitrary locations with minimal human effort. This model was run with and without treesto quantify the relative impact of that process in the microenvironment. The paper presents first results of CFD modeling for latent heat transfer near urban trees.

Upgrading the Outdoor Comfort of Suburban Residential Neighbourhoods in the Gulf Region

Alexander Kader [1]

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Many cities in the GCC states have experienced a rapid and highly unsustainable urban expansion. Supported by the low price of energy, until recently there has not been any serious economic need to implement energy efficient urban planning principles in regard to enhance the outdoor comfort within the suburban residential neighbourhoods. Car dependency is prevailing and exterior spaces are not appropriately responding to the population's needs. Large parts of the outdoor areas have been sealed; the absorbtion of heat has increased. Together with motorised traffic, the badly insulated buildings create further waste heat. These factors have caused urban heat islands. Since the GCC cities consist in very large parts of suburban residential neighbourhoods, the enhancement potential is very high. Within this research, typical neighbourhoods will be analysed regarding their outdoor spaces and urban heat islands. For a case study in Muscat/Oman various enhancement proposals will be formulated by integrating green into public and private spaces, urban agriculture, shading, reduction of sealed areas, reduction of street width, raise of albedo, improved energy efficiency of buildings, water recycling for irrigation, creating walkability and bikability. As result a toolbox will be presented, containing general improvement options, which thereafter will be evaluated and prioritised.

Influence of perceived environmental quality on outdoor thermal comfort during hot summer days in sub-tropical high-density cities

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This study investigates the inter-relationships between urban microclimate, thermal sensation, perceived environmental quality during hot summer days in sub-tropical high-density cities. A questionnaire surveys with 1,917 respondents and micrometeorological measurements was conducted in 17 sites on 15 hot summer days. Subjective assessment of sensation of meteorological variables and perceived environmental qualities was obtained in order to determine the influential factors affecting outdoor thermal comfort. The study sites, which were categorized into three types of urban settings (residential areas, streets, urban parks/waterfront), showed considerable differences in meteorological conditions. Air temperature (T_a), mean radiant temperature (T_{mrt}) and universal thermal climate index (UTCI) were found to be higher in street environment while there are no significant differences in wind speed (v). Logistic regression analysis was used to identify significant variables that affect overall thermal comfort. Measured meteorological variables were not significantly associated with overall thermal comfort while subjective sensation of meteorological variables was all significant at $\alpha = 0.001$. Among perceived environmental qualities, aesthetic satisfaction showed the largest effect size at $\alpha = 0.001$. This study offers new insights to urban design practices to consider different environmental qualities for improving outdoor thermal comfort.

Retrofit of an existing mosque in the UAE to achieve comfort in a nearly zero energy building

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With climate change and global warming as the key challenges of the 21st century, there is an immediate need to ensure that our built environment is sustainable and able to adapt to the extreme future weather events. This research study investigates the energy use and thermal comfort conditions in an existing mosque in Dubai, designed to achieve UAE's nearly zero energy building target of 90 kWh/m2 /year. Due to the hot desert climate of UAE, mosques consume a considerable amount of electricity to provide thermal comfort to their occupants. To investigate retrofit measures for such buildings, the energy demand and thermal comfort conditions of an existing mosque are evaluated using on-site measurements and operational data to inform design decisions. Numerical analysis was used to model the mosque's energy usage in a 3D simulation software, IESVE. The calibrated model output was then used to estimate overall reduction in energy use due to different passive and active retrofit measures. These solutions are in line with Dubai Green Building Regulations and Passive House Standards. On-site solar systems are also explored, to offset the high energy use intensity (EUI) of the mosque and to enable it to become a nearly zero energy building.

Australian energy efficiency policy is killing passive low energy earth building

Peter Hickson

President - Earth Building Association of Australia

I would rather be presenting, "Earth the ultimate green building material that, when combined with passive low energy design principles, provides safe, healthy, comfortable, desirable, energy efficient and sustainable buildings for the world's people into the future." Buildings that are climate change resilient and address all of the problems we face today. Buildings that meet 2050 targets for zero LCD carbon buildings, immediately.

Unfortunately, I am here to explain how earth homes can provide adaptive thermal comfort and GHG emission reductions more effectively through other means than modern "thermal shell" efficiency. To question our Australian governments' short-sightedness and ineffectiveness in reducing GHG emissions in a meaningful way. To criticise a blinkered and narrow focus set into legislation and the rating scheme used to verify compliance. The Nationwide House Energy Rating Scheme (NatHERS) is using a methodology that is erroneous, not thoroughly benchmarked against reality and without reference to a suitable metric. An approach that protects and encourages business as usual and denies best practice passive low energy architecture a reasonable compliance pathway.

Australian regulation needs to focus on promoting best practice first and mitigating worst practice second. We need recognition for Passive Low Energy Architecture and an appropriate assessment pathway.

Structural Design of a Movable Modular Shelter for Extreme Wind Conditions: A Study in Collins Bay, Antarctica.

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This paper describes structural aspects of a movable modular shelter, designed to withstand wind gusts of 200km/h in extreme cold conditions. The shelter was conceived by a mixed team of Architects and Engineers and will be used as accommodation by researchers carrying out field work in the Antarctic Peninsula. Preliminary results confirm its viability and ease of use. Considerations are made on contextual factors, such as local wind characteristics, ease of use, and structural design issues.

Investigating the performance of a ventilated wall system combined with evaporative cooling in an educational building in hot dry climate

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The global demand for energy efficient cooling strategies in non-domestic buildings is increasing, especially within African, Asian and Middle-Eastern regions. School buildings often have poor thermal comfort and poor indoor air quality (IAQ), which affect the pupils' health, education and productivity. In this paper the thermal performance of naturally ventilated walls when adding passive cooling to the wall, fabric and looked into passive cooling techniques to enhance thermal comfort and the temperature and ventilation inside the classrooms are investigated. The results demonstrated that the proposed passive cooling, in conjunction with outdoor air, could significantly reduce the temperature and enhance the thermal comfort inside the classrooms. Simulating the system using CFD reveals the system's success in reducing ambient air temperature, achieving thermal comfort, and supplying fresh air. The maximum air temperature decreased from almost 44 °C to around 22 °C under an external shade temperature of 46 °C approximately.

Towards healthy and energy efficient new homes: current issues and future directions

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Modern low energy buildings are design experiments that are only truly verified when energy and environmental performance is monitored and evaluated in practice. In the UK, increasingly stringent energy requirements and fabric performance standards have improved airtightness but with a consequence that there is an increased reliance placed on designed ventilation provision. Concerns about the effectiveness of this have been raised by professionals and researchers alike regarding the risk of inadequate ventilation, poor indoor air quality and overheating in contemporary homes.

Whilst the practice of housebuilding has seen considerable improvements over the last decade, there remains a number of common unintended consequences that need to be addressed. This paper discusses the inherent trade-offs between energy, comfort and health in housing while exploring key challenges of achieving real energy and environmental performance in practice, building on the outcomes of the HEMAC (Health Effects of Modern Airtight Construction) multidisciplinary network. An outline of the network structure and activities is presented, along with a summary of the key outcomes. A research agenda is presented, highlighting key gaps in the knowledge and future directions for research in this field.

Are our offices inclusive for women? Gender differences in thermal comfort and satisfaction in offices in Qatar and Asia

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Women's labor force participation in Asia remains low and shows a downward trend despite improved female education and significant economic growth. Several factors contribute to increased female labor force participation. Providing comfortable indoor environments to female employees is a necessary step in that direction. Are our offices inclusive for women? This study investigates the gender differences in environmental satisfaction in offices in Qatar, Japan and India from the thermal comfort and indoor environmental surveys the author conducted collecting 12,192 sets of data. Further, wider comparisons are drawn with the office environments in other Asian countries relying on the ASHRAE Database I and II containing 10,551 sets of data from seven more countries. Except in Japan and South Korea, women are more dissatisfied than men with their thermal environments in all other countries investigated. In Qatar, female dissatisfaction is significantly lower in all the other environmental parameters studied (thermal, air movement, humidity, indoor air quality, noise and lighting levels). For example, the gender differences as noted through odds ratios indicated that female subjects in Asia are 37.3 % ($p<0.001$, $N = 22, 343$) more likely to be dissatisfied with their thermal environments than their male counterparts. Similar consistent trend is noted for other environmental variables as well.

A Meta-analysis on Gender Thermal Comfort

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Various studies of gender differences in thermal requirements have proliferated in recent years. Such investigations are very important in all over the world for building design with thermal comfort approach. Several observational and laboratory thermal comfort studies reported diverse and conflicting results. Therefore, meta-analysis that statistically combines the results of several independent studies is important for synthesizing the findings, thus providing statistical evidence and better answering research questions. In the present article, the association between gender and thermal comfort was addressed using meta-analysis. The RP 884 database was exploited in the analysis. The odds ratio was the selected effect size in predicting subjects' thermal perceptions under neutrality. The random effects model was explained and rigorously justified prior to conducting meta-analysis. The obtained results revealed that gender is not a significant variable in predicting subjects' thermal perception under neutrality. Further research agendas on gender differences in thermal perceptions when feeling hot or cold are recommended.

Adapting Buildings Rating Schemes for the Extremes

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NatHERS (Nationwide House Energy Rating Scheme) which is based on simulated heating and cooling energy requirements has been adopted over a decade in Australia. Most of the houses rated and built in recent years will be in service in the mid-21st century when the Australia weather is projected in average 1 - 2 °C warmer with increasing heatwaves. Consequently, the NatHERS scheme used today will have long lasting impacts on housing energy consumption as well as household health in many years to come. Ideally, the NatHERS scheme should be adapted and improved to ensure energy efficiency of houses in a warming future climate, meanwhile achieve acceptable thermal performance during extreme weather conditions such as heatwaves. This paper overviews and discusses the technical, economic and political challenges for the NatHERS scheme to achieve these two requirements.

Applying adaptive principles: Developing guidance for planning practice

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One of the major challenges of building industry today is to provide indoor spaces allowing the occupants to make themselves comfortable while achieving low energy consumption. Considering the observed increasing temperatures and a more extreme climate, this becomes even more urgent and difficult to accomplish. It is therefore necessary to rely on approaches than contribute to sustainable building design, such as the adaptive approach to thermal comfort which postulates that people are not passive recipients of their environment but adapt behaviourally, physiologically and psychologically.

The concept of adaptive thermal comfort was formulated many decades ago and has been validated in numerous field studies. Temperature thresholds based on adaptive models have been included in international and national standards. However, the overall understanding of how to translate the adaptive principles into design practice and concepts for operating buildings is still limited. Subtask B of IEA Annex 69 addresses this gap: “Strategy and practice of adaptive thermal comfort in low energy buildings”. The subtask aims to develop guidelines for low energy buildings that include the principle of adaptive comfort. This paper discusses the challenges and gaps identified in using the principles of adaptive thermal comfort in building design and operation and outlines the contents of the imminent guideline.

Bahrain Parks: Baselining change for urban resilience

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Over the last few years, Bahrain has been increasing the number of urban parks in a bid to improve the quality of life and address public health issues related to physical inactivity; while also providing for the accelerated population growth and increasing the urban resilience of the main cities. With increased volume come the inherent difficulties around planning, design, maintenance, and management. We conducted a comprehensive nation-wide audit of parks, made it available on an online platform and accessible to all stakeholders, on an e-governance approach. In this paper, we outline the role of the project in establishing a baseline of the status quo which a) supports the creation of a coordinated strategic plan for the development of parks, b) provides empirical evidence for decision-making, and c) allows for measuring future progress against this baseline(s).

A socio-technical performance evaluation of green office buildings in the composite climate of India

Rajat Gupta, Matt Gregg and Sajal Singla

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India has one of the largest registered green building footprints in the world, yet there are limited studies investigating whether actual energy use and occupant satisfaction in such buildings is meeting expectations. This paper uses a socio-technical building performance evaluation (BPE) approach to assess the actual energy and environmental performance (during monsoon season) of two LEED platinum certified green office buildings located in the composite climate of India. The in-use energy and environmental performance of the buildings was examined using a technical building survey, energy data, environmental monitoring, along with occupant satisfaction surveys. Interestingly results showed that the two case study buildings used less energy annually than design predictions and performed better than comparative benchmarks. Building energy use had a high correlation with cooling degree days. However energy generation systems (rooftop photovoltaic systems) did not perform as intended. Indoor temperatures were found to be lower and CO2 levels higher in cellular offices, as compared to open plan offices. Occupant survey results revealed that users were satisfied with the overall design of the building, comfort levels and indoor air quality, but perceived indoor lighting to be more than required. Such empirical studies will help to build trust in the Indian building industry, which is currently shy of exposing itself to liability risk resulting from actual building performance.

SESSION 4 – Radical Comfort Thinking

Chair: Adrian Pitts

MATERIALS FOR HEAT ISLAND MITIGATION – THE STATE OF THE ART

M. Santamouris

Scientia Professor, Anita Lawrence Chair High Performance Architecture, Faculty of Built Environment, University of New South Wales, Sydney, Australia

Urban overheating may exceed 6-7^0 C compared to the surrounding suburban environment. Increased ambient temperatures have a serious impact on the energy consumption used for cooling purposes, heat related mortality and morbidity, indoor and outdoor thermal comfort, pollution levels while influence highly the economic life of cities. To counterbalance the problem, several mitigation technologies have been developed and applied in numerous large-scale urban projects. Among the proposed mitigation technologies, the development and the use of low surface temperature materials to be used in the urban fabric and the envelope of buildings, has gained increasing interest while numerous applications shown that it presents a very high mitigation potential. This paper reviews the more recent progress regarding the development and use of low surface temperature mitigation materials. The most advanced material technologies for mitigation purposes are reviewed and presented in a comparative way, while quantitative data on their thermal performance when applied in cities is given and analysed.

Passive Cooling for Comfort in Extreme Climates

Pablo La Roche[1], Arianne Ponce[2], Dongwoo Jason Yeom[3]

[1] CallisonRTKL and Cal Poly Pomona University

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This paper describes the process implemented by the authors, and in one case with students, to implement passive cooling strategies in projects in hot climates. In a warming planet, overheating is becoming an ever-important issue at all latitudes and locations, even in areas which traditionally did not have this problem. The first section describes a community center in Tecate, that includes very low-cost passive heating and cooling strategies, built by volunteers and local residents. The second section discusses recent tests in a green roof originally developed by Yeom and La Roche that combines evaporative cooling with a radiant system. The third section illustrates, through a project in development in the middle east, how these passive strategies can be combined to substantially improve outdoor thermal comfort in an extreme climate with no mechanical cooling.

Hybrid Ventilation and cooling systems: Case Study building in Singapore (Presentation only)

Wolfgang Kessling

Transsolar Energietechnik GmbH, Munich, Germany

This paper presents a case study of a Hybrid system design in the student hub space at a university building in Singapore. It outlines how the typical client's comfort questions were addressed during the design process arising from the new design approach adopted. To reassure the clients about the validity of the innovative approach adopted the performance of a conventional air conditioning system was systematically compared to the performance of a Hybrid System Design using dynamical thermal simulation. Relevant comfort parameters were compared on an hourly time basis with additional focus added on space humidity. While challenging the basic design assumptions of client brief and developing the schematic architectural design, the path to a high comfort – low tech – low energy design was made transparent, so informing the client and design team and providing confidence to the investors in this pioneering Hybrid building.

Boosting Comfort Locally with Personal Micro-Climate Systems

Risto Kosonen[1,2], Weixin Zhao[1], Sami Lestinen[1], Chengchu Yan[2] and Simo Kilpeläinen[1]

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The commonly used total volume systems cannot provide high quality indoor climates in an energy efficient manner. Also standard systems are not able to guarantee the comfort and air quality demands of individuals in spaces. Thus, there is need to introduce systems that can provide user-centered climate systems in which users are able to control their own indoor micro-environments. Micro-climate systems makes it possible to enhance users' perception of their local indoor climate conditions. With personal ventilation, it is possible to provide clean air close to the breathing zone and also control thermal comfort locally. Another possibility to create local micro-environments is by using ceiling integrated systems that divide spaces into different subzones. In the near future, it will be possible to develop room systems that can be constantly reacting to human physiological signals to maintain conditions across a space that best fit the comfort requirements of individuals within it.

WORKSHOP 6 - Personal & Radiant Systems

Chairs: Risto Kosonen
Bjarne Olesen

Localised air conditioning: comfort with sustainable energy demand

James Trevelyan

The University of Western Australia

Close Comfort Pty Ltd

Emissions from rapidly expanding use of room air conditioning in emerging economies is likely to increase global temperatures by 0.5 °C by 2100. However global greenhouse emissions need to be eliminated by 2045 – 2055 to stabilize warming at 1.5 °C. To meet this requirement, an affordable, alternative, low-energy, low emission technology needs to be deployed on a mass scale within 25 years. Since new technologies typically take 30 – 40 years to deploy globally, it will be easier with technologies that are available now.

Experience demonstrates that small portable air conditioners (spot coolers) with appropriate air delivery technology can meet this need. They create a localized micro-climate for up to three people providing acceptable comfort using only 180 – 300 Watts. They work in any building with no requirement for installation, piping, draft sealing, insulation, or structural modifications. They also work outdoors in sheltered locations.

For sleeping in extremely hot conditions, a specially designed bed tent retains a layer of conditioned air above a bed and provides protection from biting insects. Air delivery is designed to create sufficient air movement past exposed parts of the head and neck of users to gain about two degrees of additional perceived cooling, enhancing comfort sensation.

Phase Change Materials as part of building construction systems and indoor passive thermal regulators within the Sonoran Desert

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This work studies and compares the thermal performance of construction systems including adobe, insulation, and Phase Change Materials (PCM) based on the amount of thermally comfortable hours provided within indoor spaces. The study is conducted through an energy computer simulation, using past, present, and future climatic data corresponding to Hermosillo, a Mexican municipality within the Sonoran desert, which is one of the most vulnerable regions to climate change in Mexico, and where outdoor temperature oscillate 14°C in average giving extreme thermal conditions. It appears the earth materials, such as adobe, are still the materials with most thermal mass effects. On the other hand, PCMs also present a very high performance relating to thermal mass effects (very close to a thick adobe wall), but with less material allowing envelopes to be lighter.

Development of an innovative compact hybrid electrical-thermal storage system for historic building integrated applications in the Mediterranean climate.

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Currently in the EU, there are limited examples of operationally integrated solutions capable of achieving optimal interaction of energy networks, combining both electricity and heat-cooling energy supply and storage. There is thus, a need for the efficient use of renewable energy resources through hybrid systems utilising generation and storage of energy. The present study proposes a novel concept for the development of an innovative compact hybrid electrical-thermal storage system for stand-alone and district connected buildings. The proposed hybrid storages will be used to upgrade existing building configurations and will be monitored in real-life operation in a historic building in Cyprus. The building has been selected to be part of a hands-on technology exhibition area of renewable energy systems complimented with visual means to enhance the experience of visitors. The RES systems will be enhanced with enabling technologies offering the benefits of smart digitalised home solutions that can seamlessly be integrated in the neighbouring communities / districts to form energy communities. The municipality is to use the systems as a hands-on experience for informing society about the use of new technologies in their homes capable of offering a transition to the low-carbon economy achieving high levels of energy savings. Moreover, the integration of such systems in this specific application is to be used as an exploration of the sensitive issue of the architectural integration of technologically advanced systems into the listed buildings of historical centers. The concept presented herein is part of the ongoing research programme HYBUILD, which is funded by the European Union through HORIZON 2020.

Wintry Thermal Environment and Domestic Energy Use in Nepal

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Nepal is a mountainous country with low energy use so far and its climatic patterns remarkably differ from one place to another due to its geographical variation. In the North summer is cool and winter severe, while in the South summer is tropical and winter is mild. Indoor thermal environment and household energy use of residential buildings has attracted considerable attention however, there has not been sufficient number of studies in the thermal environment and household energy use in Nepal. In this study, we aim to analyze the current situation of household energy use and indoor thermal environment of residential buildings in different ecological regions of Nepal. This study was carried out in Mountain, Hill and Terai regions in Nepal from 21 December, 2017 to 20 January, 2018. Indoor and outdoor air temperature and humidity were measured with the help of data logger for every 10-minute interval from 5 households from each region. The mass of firewood used was also measured at those houses. Household energy-use data of 516 houses were collected by the method of questionnaire survey. We found that mean indoor temperature was 8.6℃, 12.8℃ and 16℃ in Mountain, Hill and Terai regions respectively. Based on this field study, we concluded that firewood is the important source of household energy for cooking. The present finding suggests that an intensive and extensive improvements of the indoor thermal environment together with less use of energy must be responsible in the winter season.

Indoor air quality, cold stress, and thermal comfort in multi-family timber-frame buildings

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This paper examines the indoor air quality, cold stress, and occupants' comfort in multi-family timber-frame buildings located in Hartford County, Connecticut, United States. The study considered the physical measurements of environmental variables (such as temperature, relative humidity, air velocity, and CO_2 concentration) at 0.6m, 1.1m, and 1.7m above the floor level as specified in the ASHRAE Standard 55. The wet-bulb globe temperature (WBGT) was computed using the variables measured during the survey to understand the temperature at which the residents will be subject to cold stress. The results showed the mean temperatures at various heights varied from 17.1°C-20.3°C. The average relative humidity (RH) ranged from 32%-46%. The average CO_2 values differed from 405.9ppm-482.8ppm. The mean air velocity of 0.1m/s was measured across different levels. Overall, the mean temperature of 18.6°C and an average RH of 39% were recorded in the buildings. The overall average indoor temperature was below the comfort temperature thresholds (20.3°C/23.9°C) recommended by ASHRAE. The results showed the occupants might be prone to cold discomfort. Higher CO_2 values were recorded in the evening and night-time. Behavioural actions of some of the occupants as observed during the field measurements might be a contributing factor to the higher CO_2 values measured at these periods. The occupants reported stiffness and unpleasant odours in the evening and night-time while the measured CO_2 values during the period supported the complaints (CO_2 values above 700ppm). However, the CO_2 values were below the acceptable level recommended by ASHRAE (the values are below 1,000ppm) for healthy indoor conditions in buildings. By applying the WBGT stress index to find the threshold for occupants, the study recommends the WBGT of 13.6°C as a cold stress index for vulnerable occupants in timber-frame buildings during the cold season. The research revealed that an increase in CO_2 level also increases the air velocity while the indoor air quality decreases within the spaces. The study found out that behavioural actions of occupants can affect the indoor air quality of buildings.

Sustainability Literacy and Higher Education; Paradigm and Challenges in the Built Environment of the Gulf Region

Kheira Anissa Tabet Aoul

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There is growing movement to transform educational systems into high impact education on sustainability that better prepares students to live in and address this changing world. Achievements are however contextually variable. Educating and training tomorrow's professionals who abide by and deliver an ecologically sensitive design is a critical mission that has been extensively embraced by architectural, design and engineering schools worldwide. Similarly, the Architectural Engineering program at the United Arab Emirates University has embedded sustainability throughout its curriculum, resulting in students technically knowledgeable in delivering high performing buildings. However, while the program has delivered the technical knowledge, the analytical and problem-solving skills to meet the green building targets, it has not necessarily translated into a higher awareness level and ethical commitment to sustainability. This may be particularly evident in the Gulf countries, where high earnings coupled with subsidized energy, do not reflect the true energy usage. The ethical commitment to sustainable development in the built environment remains yet to be fully reached. This paper presents some educational activities developed in an elective course aiming to bridge the "ethical commitment" gap. Among these, the retrofitting exercise to greener standards of the student's own home yielded substantial benefits beyond the targeted objectives. The energy and water usage in the home was critically assessed in relation to the house building design and construction. In addition, occupants' lifestyle, behaviour and attitudes were explored through observations and interviews and were an eye opener, triggering inquisitive responsiveness. The critical overview of the building and its occupants' behaviour played a significant role in understanding the intricate relationships governing the targeted goal, highlighting that the only way to address the issues is collectively, calling on everyone involvement in response to moral responsibility. Above all, this paper aims to foster a wider debate on contextual educational strategies to really meet the sustainability targets.

Envisioning a climate adaptation plan for the city of São Paulo: a starting-point framework

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The world's cities are growing in size and number and the warming pattern has changed. Sao Paulo is the 5th biggest megacity in the world and the overtime data observation reveals a progressive temperature rising: from the measuring start in 1933, there was an increase in annual average temperature of 3oC. Besides that, future climate scenarios point out an increase in discomfort hours. In this context, this work envisions a climate adaptation plan for Sao Paulo, as a starting-point framework, in three scales: 1) metropolitan scale, as a result of a local study of the impact of vegetation suppression in land surface temperature (MODIS); 2) local scale, including measured and simulated green infrastructure as well as the benefits of mutual shading of buildings, balancing urban density with climate amenities (ENVI-met); 3) building scale: future climate scenarios simulation including the new stock of residential multifamily buildings (TAS/EDSL). A radical change in building regulations must take place, including climate change considerations for the life span of buildings. The aim is to explore design-related adaptation measures and provide subsidies for public policies, establishing objectives, roles and actors, improving urban and building standards, progressively adding recommendations, incentives or requirements, besides monitoring and evaluating.

Energy & Thermal Comfort Performance Evaluation of Net Zero Energy Building in Hot Dry Climate – A case study

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The paper presents the case study of a Net-Zero Energy Building (NZEB) located within the CEPT University campus, Ahmedabad. It starts with a narration on design and construction and provides an overview of the building envelope characteristics and operational strategies. Custom design and operation of the building management system (BMS) in order to synchronize the electrical consumption and generation using solar PV is described. The paper analyses the energy consumption and generation in NZEB during 24 months of operation (Jan-2017 to Dec-2018). Hourly end use energy consumption and generation data were analyzed to understand the performance of the envelope and electro-mechanical systems. Along with energy consumption analysis, the paper also includes the study of occupant comfort. The occupant comfort data was correlated with the hourly outdoor weather data collected using an automated weather station installed at the NZEB. This paper is an attempt to share the learnings in regard to the design, construction, operation, and maintenance of the NZEB in India.

Sustainability and "Low-energy" building design in high density urban cities - [Cairo as a case-study]

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The rapid increasing of urbanization all over the world, then large and mega cities are growing in number, resulting in increase of: population, pollution, and traffic Complexity. Thus incorporating energy efficiency and sustainable design features into all contemporary buildings has become a high priority for owners, designers, and governments.

The research methodology follows: Literature, Analytical and Comparative/analytical reviews respectively; examines the concept of "low-energy" building, investigates how urban density might affect building energy design in high density cities. Using Cairo as a case-study, the characteristics and factors affecting "low-energy" building design techniques are evaluated. The current energy situation in Egypt is explained and considerations for energy efficiency in high density conditions are discussed.

The research aims to draw-out a frame-work for best strategies and passive design techniques of "low-energy" buildings appropriate for application in dense environments. through using the "Base-case" model vs. "Low-energy" model using "design builder" simulation tool; to compare the impact of applying different strategies: [Orientation- Façade design - glazing materials...]. The research find-out that the "low-energy" designs techniques may reduce energy consumption by about (35:50 % or more). Such results may help designers and owners to make their decisions promoting energy efficiency in: new and retrofit buildings.

WORKSHOP 9 - The Role of Natural Ventilation in Future Comfort Design

Chairs: Jose Roberto Garcia Chavez
Ulrike Passe

Modeling natural ventilation in commercial buildings using data-driven methods

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This work summarizes findings from the long-term research on modeling occupants' interactions with operable windows in commercial buildings. For that purpose, the monitoring data from two commercial buildings located in Germany with natural and mixed mode ventilations were analysed and suitable machine learning modeling approaches were investigated. In particular, three research questions were addressed. Firstly, the conventional machine learning was explored for developing the occupant-wise calibrated occupant behaviour (OB) models. Secondly, large scale data were used to develop a deep learning-based model that was tuned on a building level. Eventually, the predictive model for natural ventilation was developed for the application in model predictive control (MPC) in real-time building automation systems (BAS). The results showed, that both the random forest algorithm and the deep neural network could model imbalanced OB data with a satisfying accuracy.

A paradigm shift in comfort design for Singapore

Wolfgang Kessling and Martin Engelhardt

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In Singapore, where low temperature air conditioning represents the well-established standard, leaving this conventional path and introducing a high comfort design with higher room air settings in combination with breeze and excellent fresh air supply is almost precluded by the system and poses a challenge to clients and design teams. There are few buildings designed using good passive climatic design while exploiting natural ventilation alternating in operation with a Hybrid System Design for Adaptive Comfort. Adaptive Comfort concepts deliver the same comfort but with lower reliance on mechanical systems. Combined with Hybrid System Design, the ventilation and cooling systems can be substantially downsized, reducing investment cost as well as substantially reducing energy demand for ventilation and space cooling. This presentation outlines the underlying principles used in recent building projects in Singapore and points the way to a new design paradigm for low energy buildings in hot climates.

Energy retrofit for buildings in Iraq: Insulation Parametric Study

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The target of this research is to investigate the potential of reducing energy demand for residential buildings in Iraq. In this article the effect of thermal insulation for exterior walls and roofs in existing buildings is tested. Characteristics of t ypical existing buildings were chosen based on the online survey conducted in 2014 by the author.

To test the different scenarios, a 3D model was constructed and simulated using TRNSYS. Parameters such as HVAC, thermal storage capacity, shading, infiltration rates, and temperature settings are defined here as constants. In the reference building scenario, the building has no insulation. 8 more scenarios related to wall insulation were tested (4 with interior and 4 with exterior insulation). For the roof 8 further scenarios were tested as well.

The results show that insulation the roof results in energy saving up to 31%; however, using only 6 cm of insulation proved to be the optimal solution, with savings up to 27% compared to 31% when 18 cm insulation was used. The effect of wall insulation was lower. With savings up to 14% using 18 cm external wall insulation and 11% with 6 cm insulation. In roof and walls, exterior insulation performed slightly better than interior insulation.

Thermal Comfort and Energy Use of Affordable Housing in Ahmedabad, India

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'Housing for all – 2022', a large-scale housing initiative was launched in 2015 by the Indian government for providing quality affordable housing to the lower economic segment by the year 2022. Occupant thermal comfort is one of the significant aspects of liveability and applies to affordable housing as well. These houses have low energy consumption as of now, however as incomes and comfort expectations increase, energy use and related costs in this segment are expected to surge. So far, comfort field studies in affordable houses in India remains a subject largely neglected. This paper reports findings of the thermal comfort conditions and energy use of 20 houses in three affordable housing developments located in Ahmedabad, India during winter season (November-February). The analysis discusses results from data collected using three methods - Long-term monitoring of household energy use and indoor environment parameters of temperature and relative humidity, instantaneous measurements of thermal comfort conditions and right-here-right-now thermal comfort surveys. It is observed that average daily energy use ranges from 0.5 - 6.75 kWh and is dependent on appliance ownership and occupant behaviour and is base load driven in these houses. 66% of the occupants reported being comfortable in their thermal environment during the survey period. The conclusions from this study will be of meaning to various stakeholders in the affordable housing segment.

The influence of the improved Saudi system of houses' setbacks on indoor comfort conditions

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The high levels of energy consumed for cooling purposes in the Gulf region highlight the importance of satisfying thermal comfort demands passively or at least reducing the gap towards that. Recently, the Saudi Ministry of Municipal and Rural Affairs improved the houses' setbacks regulations. These improvements increase the built-up area to 70% of the property's area and allow reducing the previously required setbacks by up to 100% of no more than two sides. This paper, up to the authors' knowledge, is the first attempt to investigate the influence of the improved Saudi system of houses' setbacks on the cooling loads and internal thermal comfort conditions. Implementing Design-Builder software, 50% and 0% of setbacks cases were applied to a villa in Riyadh. These cases were investigated in Muscat considering the climatic, social, and cultural similarities of the Gulf region. The corresponding reductions in the cooling loads during summer were around 6.3% and 21.6% in Riyadh and almost 12.3% and 15.1% in Muscat. The predicted mean votes of the base cases and the investigated cases fell in the (slightly warm) category. Exploring the influence of other cases allowed by the system is recommended in Riyadh and other cities in the Gulf region.

Evaluating the effect on thermal comfort and energy use of applying the Passivhaus standard to a dwelling in a hot humid climate – a case study in Jakarta, Indonesia

Roy Candra Sigalingging, David Chow and Steve Sharples

University of Liverpool, UK, School of Architecture

Houses built in tropical countries will experience hot and humid climatic conditions, with high levels of moisture. Together with moisture builds up by occupants' activity, ventilation for such housing will lead to very high levels of indoor relative humidity. The use of air conditioning to cool rooms and reduce relative humidity in dwellings is an energy-intensive approach but it is also energy-inefficient as the conditioned air is lost through the building envelope via ventilation and air infiltration. The German Passivhaus standard's approach in tropical housing might be effective in preserving stable interior temperatures, nevertheless special attention is needed to the removal of excess moisture. The objective of this research was to investigate the thermal comfort and energy-saving implications of applying Passivhaus principles to existing urban row houses in Jakarta, Indonesia. The goal was to achieve the lowest possible carbon emission building whilst maintaining a comfortable and healthy environment. The software model of the existing dwelling was built in IES software and was checked against field measurements of air temperature and relative humidity made in the house. Parametric modelling involved gradually improving insulation levels and air-tightness in the house until the Passivhaus standards were reached. Analyses of the results enabled the optimum insulation and air-tightness settings to be determined for minimizing cooling and dehumidification energy use in the air-conditioning system.

Applications of Evaporative Cooling for Thermal Comfort

Craig Farnham

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Evaporative cooling (EC) is seeing increasing attention as a low-energy method to increase thermal comfort in hot climates. Although EC can reduce air temperatures using the latent heat of water, the accompanying rise in humidity and the limited achievable temperature drop may discourage adoption of EC systems. Here, a short review of common EC system types and the basic physics of EC applied in thermal comfort models are presented. Some current research on EC and thermal comfort is reviewed for the purpose of sparking discussion of EC in the context of thermal comfort.

Dry Mist Systems and its impact on Thermal Comfort for the Tropics

Zheng Kai and Wong Nyuk Hien

University of Singapore

Tropical countries, like Singapore, are hot and humid throughout the year. Coupled with the Urban Heat Island effect from rapid urbanisation, Singapore has seen a long-term increase in annual average temperatures over the years. One solution is the use of misting systems that tap on the principle of latent heat of vaporisation to provide cooling. This paper specifically addresses the use of "Dry Mist" systems, where the sprays are of ultra-fine droplet size and do not cause a wet sensation upon contact, thus the name "Dry Mist".

These systems have typically been employed in temperate countries, like Japan, and has not been widely employed in Singapore due to the seeming low potential for cooling in humid countries. However, such systems can still be effective during hot afternoons, where the wet bulb depression can go between 5-7oC. Thus, the use of Dry Mist and its impact on human thermal comfort is worth studying.

Due to the impact on skin temperature and wetness, the Standard Effective Temperature (SET*) has typically been used to represent the change in thermal comfort from Dry Mists. However, these values are assumed from the human metabolic rate and are typically used for sweating on the human skin. Thus, its appropriateness as a suitable comfort index may be questionable. Another possible comfort index is the mean skin temperature, but the measurement process is tedious and intrusive as it involves placing equipment on at least 10 parts of the human body. Many studies have tried using thermal mannequins to cover this gap, but this paper hopes to address this issue by testing if thermal comfort from misting can be simplified to just a few variables that are easy to measure. All variables tested will be analysed statistically and the variables with the highest impacts will be chosen.

Performance Evaluation of Indirect-Direct Evaporative Cooling System In Hot & Dry Climate

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The commercial and residential sector demands high cooling requirement, which is mostly achieved by using conventional cooling systems like split ACs, chillers or VRF. These systems currently produce 100 MT of CO2 per annum and hence contribute significantly to carbon emissions. To mitigate such environmental impacts, using low energy cooling systems like an indirect-direct evaporative cooling system (IDEC) is an energy efficient alternative as it uses energy only for pumping water and blowing air.

This study evaluates the cooling performance of IDECs. The wet bulb effectiveness (WBE %) was calculated from the hourly measured values of air temperature (Ta °C) and relative humidity (RH %). These parameters were measured at inlet and supply air. Energy consumption of the IDEC, air blower fan, and water pump were monitored every hour. Thermal comfort surveys were conducted to establish a relation between the effectiveness of IDECs, the cooling energy consumption and degree of occupants' comfort. ΔTa of 5- 6 °C and saturation deficit of as 30-35% was observed. During August-October WBE varied from 55-83% with an energy consumption range of 29-30 kWh. Whereas, for November-December, WBE varied from 41-67% with energy consumption range of 23-28 kWh.

Reclaiming refugee agency and its implications for shelter design in refugee camps

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Refugee agency refers to the notion of decision making exercised by forced migrants, and their efforts aimed at improving life in the context of displacement. As such, it has emerged as a useful concept to channel discussions about the challenges of current refugee encampment practices, which we argue encompasses consequences for the design and provision of shelter solutions. Building on the evidence collected in selected refugee camps of Jordan and Ethiopia, we suggest that acknowledging and incorporating the voices of refugees can not only enhance their well-being in climatically, socially and politically challenging environments, but it could also be beneficial to other actors such as humanitarian agencies and host governments. While we recognize the constrains arising in these contexts, we focus on the importance of adaptations and customization of shelters that we found to be the leitmotiv and, more critically, a fundamental humanizing factor of refugee experience in camps. The refugees' freedom to make choices about their own shelters can then be used to rethink how to deliver better environments in which camp inhabitants can live in dignity. Although engineering design can only facilitate agency, rather than give it, it could help build the consensus about the pre-requisites of what constitutes truly 'appropriate' shelters.

The architecture of refugees

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It is widely known that global warming could lead to a humanitarian crisis. In fact, the environmental and climatic conditions needed by people to survive are being increasingly disrupted. Europe is facing the worst displacement crisis since World War II, according to the United Nations High Commissioner for Refugees (UNHCR). There are more than 68 million refugees living in camps in harsh environments and extreme climates. Shelters provided are mostly inadequate due to several factors, such as space, privacy or culture. In addition, the thermal performance and the conditions inside shelters could cause health problems such as thermal stress or, in the worst case scenario, they could lead to death. This is an extremely important task, as we need a quick scalable housing solution that can create a space that meets comfort conditions in the face of a crisis of unknown duration. Thus, this research is focused on the assessment of thermal conditions in shelters from different climatic zones: Jordan, Afghanistan and South Sudan, and it also explores the possibility of achieving better results in a different country; following a previous study of the conditions in each country in order to fully understand their basic needs.

Siting considerations for a shelter in the extreme cold of Antarctica

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Shelters in extremely cold regions are highly influenced by their site locations and significant improvements in their thermal performance can be achieved by simply orienting them to optimise the potential solar heat gains available and minimising the impacts of cold, strong winds around the structure. This paper presents of numerical simulations of insolation and wind exposure on a remote site in Collis Bay, King George Island in Antarctica where a 'polar Lodge' was erected and tested in February 2019. The results of the study clearly demonstrated the complexity of issues involved in optimally positioning a structure in extreme conditions and its entrance to take maximum advantage of the energetic landscapes and minimising its potential to fail for a range of weather related reasons. The paper shows that in this particular location, with predominant winds from the south east and high latitude, a windbreak could double as heat storage during the summer.

Thermal Performance of a Movable Modular Shelter for Extreme Cold Conditions: A Study in Collins Bay, Antarctica

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This paper summarizes the results of a pilot study on the performance of a movable modular shelter in extreme cold conditions. The shelter was designed by a mixed team of Architects and Engineers and will be used by researchers carrying out field work in the Antarctic Peninsula. Preliminary results confirm its viability, ease of use, and satisfactory thermal comfort performance. Considerations are made on contextual factors, such as comfort expectations, local climate characteristics, and design construction issues.

Adaptive behaviours of elderly for cooling in Tropics: Field studies in naturally-ventilated aged care homes

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Ageing population is a key global challenge in next several decades and majority of this demographic shift is confined in Asia. Thus a burgeoning demand on care homes for elders is evident and continues to grow. Elderly are more susceptible to the impacts of the extreme temperatures due to decreasing trend in the ability of regulating body temperatures. Thus the elders perceive overheated environments as thermally comfortable when it poses threats to their health. This study experimentally investigated the adaptive behaviours of elders for cooling in naturally ventilated aged care homes in Tropical city of Colombo, Sri-Lanka. Onsite field studies are consist of simultaneous personal monitoring and questionnaire surveys. Results explicitly prove indoor environments are overheated. Mean thermal sensation of 0.99 with a mean thermal preference of -0.63 informs the need of cooler indoor environment. Mean neutrality temperature of elders is 30.2°C. Discrepancy between simple regression analysis in estimating the neutral temperature establishes the presence of behavioural adaptations. The most prominent adaptive behaviours of elders to satisfy cooler sensations are changing the place by going outside and modification of indoor thermal environment by switching on fans. Moving towards open areas such as courtyards and veranda plays an important role in thermal adaptation. Clothing adjustments and bathing are less preferred thermal adaptation strategies of elders in summer. Thus these findings highlight the importance of integrating semi outdoor spaces in the designs of aged care homes to promote heat resilience of elders in tropical climates.

Experimental assessment of thermal comfort conditions in educational buildings in Cyprus using different ventilation strategies and window opening patterns

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This paper presents findings from extensive field surveys of educational architecture in Cyprus during the winter and summer periods, and simultaneously explores the impact of natural ventilation on the indoor thermal environment. The study included seasonal indoor and outdoor monitoring of physical parameters. During the summer, the objective of the ventilation experiments was to achieve the most effective cooling strategy; thus, both single-sided and cross-ventilation strategies were employed for different times of the day in four classrooms. During the winter, the objective was to achieve optimum air quality with the least adverse impact on thermal comfort; thus, window operation patterns of single-sided ventilation strategies were examined. During the winter period, the operative temperature is below the acceptable comfort zone, while during the summer period, the findings show the vulnerability of the occupants to summertime temperatures. During the winter, a closed classroom shows the best results in terms of operative temperature; however, this conflicts with the air quality. During the summer, the case of cross-ventilation, both during the day and night, is the most efficient and operative way to passively cool educational architecture. The results of the experiments carried out in this study can be applied to inform strategies aimed at improving thermal comfort and reducing energy use in both new and existing educational buildings.

Impact of urban geometry on indoor air temperature and cooling energy consumption in traditional and formal urban environments

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This study explores the effect of outdoor microclimatic environment on indoor conditions in a tropical warm-humid climate. An indoor air temperature and building energy performance analysis is carried out for the real case-study areas to examine the impact of urban geometry on building indoor conditions. The study incorporates microclimatic data from CFD, micro-climatic tool ENVI-met into building energy performance analysis using IES-VE. Findings reveal that diversity in urban geometry in deep urban canyons is helpful in reducing the indoor air temperature and cooling load. On average, cooling load in model rooms in the formal area is 21% higher for 1st floors (40% for top floors) compared to the corresponding rooms in the traditional area. In terms of solar gains, the difference was 30% for the 1st floors and 91% for the top floors, with rooms in the formal area having the higher ranges. Furthermore, the room air temperature in the traditional area was found to be 0.6-1.6 ^{0}C lower than those in the formal area.

Temperature studies of the effect of glazed facades and vegetation on urban heat islands in Brasilia

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Brasilia is the designed capital city of Brazil inaugurated in 1960. Its plane like form has in its wings the residential sectors, and in the centre of the main body are sectors which compose the gregarious scale like the hotel and commercial sectors. Although Brasilia is not even 60 years old, it already has more than two million people and urban problems similar to secular metropolisis. As the city grows in an incessant pace, greenery is left aside in favour of buildings, which are now more robust and completely glazed, like those commonly found in countries north of the equator. This insanity of building relentlessly glass boxes in the tropics, is a trend that needs to be reversed and calls for an urgent sustainable agenda. This research aimed to analyze the consequences of this new architectural language, its influence on urban heat islands, microclimates, healthiness, and environmental comfort. Urban fragments formed by edifices with glazed envelopes were compared to buildings with sun protection elements. Urban spaces with and without vegetation were also compared. Thermographic photos illustrate the thermal intensity of distinct surfaces. Large temperature differences of more than 10ºC were registered on different surfaces and reflected on the adjacent microclimates, causing discomfort to the pedestrians, and an indication of diurnal urban heat islands.

Innovation in Construction: the case of BIPV customization in extreme climates

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Building Integrated Photovoltaics (BIPV) represents one of the many areas of construction innovation, which have evolved to address global environmental concerns caused by the negative impact of fossil fuel consumption. Existing literature however asserts that despite significant benefits, knowledge and communication are barriers to innovation. In addition, the limited degree of BIPV innovation adaptability to contextual/regional customer specifics further suppress its the uptake. The aim of this research is thus, to investigate custom BIPV products –as an example of technological innovation in hot climate conditions. Secondly, the study presents the development of a novel BIPV communication approach towards improved adoption/uptake. The dual aim is to design custom BIPV products for hot climates, which meet customer preference to increase adoption. Case study reviews following the Design Research Methodology (DRM) was used to understudy both objectives. The reviews report cooling load reduction up to 1.9% and energy efficiency increase up to 10% in referred BIPV custom strategies. Towards BIPV communication, 82% of respondents (n=69) are specifically guided by communicated environmental and economic benefits. Also, 60.2% (n=103) focus on the performance of the system and 30.3% on the cost. The BIPV and architecture communities will potentially benefit from this on-going investigation based on its significance towards a more human-centred green future.

Non-Invasive Assessments of Thermal Discomfort in Real Time

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People make distinctive gestures or movements when they are thermally uncomfortable, for example self-hugging when uncomfortably cold or brow-wiping when hot. Extreme thermal conditions reinforce this tendency. These gestures may be affected by various competing motivations such as emotional or physiological responses and cultural traditions. Several software applications can now identify and track movements of a person's skeletal joints or keypoints in real time; these include hands, arms, elbows, head, etc.. A procedure was created to identify gestures related to thermal discomfort and then to decide if a person is uncomfortably warm or cold. When a discomfort-related gesture is detected, it is scored based on the type of gesture and recognition confidence. This score is fed into a "Thermal Comfort Index" (TCI). A zero TCI corresponds to thermal neutrality and higher positive or negative values correspond to feelings of warmth or cold, respectively. The TCI diverges further from zero when the detected gestures are frequent or intense. A key feature is a "library of gestures"; the procedure consults this library to determine if a particular gesture might be associated with thermal discomfort. This method was applied to a single person but could also be applied to large groups. This method of tracking thermal discomfort is well suited for locations where occupants are not easily able to communicate thermal preferences.

The thermal and energy demand of Solar Decathlon Middle East prototypes and its classification by climatic seasons

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For an architect today, the method to design a passive house in cold weather and the choice of the Architectural Actions (AA), are clearly established. When the question comes to how to build a passive house in hot, and extreme hot climates, the strategies are poor and often results of a combination of western strategies with a local relook. From several visits in Middle East countries, Saudi Arabia, UAE, Oman, Palestine, Qatar, we concluded that the strategy for low consumption houses is not established yet and poorly grasped.

Several reasons, as energy prices, invite designers and owners to rely on over usage of air-conditioning systems as measures to catch up on poor bioclimatic design. The method of the "Climatic Seasons" proposes an approach on bioclimatic design for extreme hot climates from an architect point of view. It is based on a Cooling Degrees Days (CDD) and Heating Degrees Days (HDD) approach. Local climates are classified according to the energy-hunger of six situations of the exterior temperature during night/day : cold/cold, cold/cool, cool/warm, cold/hot, cool/hot, and hot/hot as CDD and HDD of the twelve month of the year. This will create two main "house situations": the house is closed or open to the exterior. We will associate passive strategies, "architectural actions", to these two different ways to live in the house .

Several prototypes have been constructed and tested for the Solar Decathlon Middle East 2018, in November 2018 in Dubai (https://www.solardecathlonme.com/). This competition gathered 15 teams composed of students and scientists from all over the world. Each team proposed different architectural actions to reach low energy consumption, this paper analyses them and proposed a classification related to every climatic season, and discuss about their efficiency related to the results of the competition.

Monitoring, Evaluating and Optimizing the Energy Supply of a Photovoltaic System of a Zero-Energy-Building in Oman: Case Study of the GUtech EcoHaus

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Extreme climates are a challenge as well as an opportunity for creating energy-efficient buildings. In the very hot climate of Oman, the intense solar radiation is the cause for a high demand for cooling energy, but also the reason for a potentially high supply of solar energy. This paper is a case study of the energy supply from a photovoltaic system (PV) for a zero-energy-building, the GUtech EcoHaus in Oman. It reports the performance of the PV system over three 12-month periods as well as soiling problems and cleaning practices. It concludes that the performance is as expected and maintenance is within the range of reasonable effort. This is in fact a very important message in a region where despite excellent conditions of solar irradiance the wide-spread application of PV systems, e.g. in residential units, is still hindered by the long-held assumption that this technology would underperform under the extreme climatic conditions, especially heat and dust. Further, the study looks into ways to optimize the performance through space-efficiency, tilt angle, capacity factor and tariff structure. The results are recommendations for the installation of PV systems on new and existing buildings (retrofit). The paper gives an outlook on policies for promoting PV systems in Oman to reduce energy subsidies as well as developing job opportunities for local small-and-medium enterprises (SMEs).

Responsiveness and resilience of existing dwellings in warm-humid climate zone to changing climate

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Vernacular building designs have evolved over time to appropriately regulate comfortable indoor conditions in response to outdoor conditions. While climate change is imminent, the specific changes in climatic conditions are uncertain for any given location. The climatic response of vernacular dwellings thus needs to be studied for possible climate change variations, and their ability to still maintain comfort. Progressive nations such as India are characterized by more than 60% vernacular dwellings. However, the occupants in these dwellings are increasingly aspiring for a modern life. This is evident in their adoption to modern materials and building typologies and the dependence on electro-mechanical appliances to maintain indoor thermal comfort.

Inhabitants of vernacular dwellings relied on their physiological resilience to withstand a wide temperature range. This narrows down with exposure to conditioned indoor environments, and is evident with increasing energy consumption to maintain comfort. The current study aims to evaluate the ability of vernacular dwellings to respond to possible climate change variations and maintain comfortable conditions in the ensuing indoor environments. This study also investigates the climate responsiveness and thermal performance of dwellings that are undergoing modern transitions, based on a real-time and simulation assessment of a vernacular habitation in Suggenahalli village, India.

An Adaptive Thermal Comfort Model for Residential Buildings in Iraq

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In Iraq, the temperature reaches around 0 °C in winter and 50 °C in summer. Aiming at providing thermal comfort for people, studies have been advocating developing innovative thermally responsive designs or adopting traditional architecture's passive design strategies. However, to develop appropriate solutions for the country, it is critical to determine the thermal comfort limits to define the targeted thermal performance of buildings. This research worked on defining Iraqis' thermal comfort limits in residential buildings for two reasons. First, they are the dominant building type in the country. Second, to inform the design of large housing developments Iraq is planning to have to satisfy large housing needs. Exploring previous literature in Iraq or regional countries shows that residential thermal comfort limits for people have not been defined properly. To achieve this aim, the research conducted thermal comfort survey in four Iraqi cities for a year. Nearly 4800 thermal comfort votes were recorded by 90 participants. The results show that the lower thermal comfort Globe temperature in winter is 17 °C and the highest acceptable Globe temperature in summer is 33 °C.

Comfort, ventilation and health issues in dwellings of Ho Chi Minh City

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Ho Chi Minh City, Vietnam is a location in which a number of environmental factors come together in such a way as to create concerns for comfort and health of building occupants. The city is located in a tropical monsoon climate which brings long periods of hot humid weather and there is evidence that climatic extremes have become more prominent in recent years, and these are being exacerbated by urban heat island effects. Ho Chi Minh City has undergone a rapid period of urbanisation and perhaps more importantly densification; this increasing density means that air flow through circulation routes in and around buildings is being compromised. The spaces between buildings are being encroached upon, and opportunities for crossventilation and natural cooling are diminishing. Environmental conditions within buildings are often very warm and humid and in addition could harbour and give rise to spread of, harmful bacteria/viruses/fungal intrusions. This paper presents information on typologies of dwellings and potential risks; it includes observations and measurements from a range of dwelling types gained at first hand. Whilst the research does not provide full solutions it indicates where risks exists and thus where future research efforts might be concentrated.

Learning from Building Failures (Presentation only)

Samuel Domínguez Amarillo

In a rapidly changing world it is important to be able to change the built environment to cope with ever more extreme conditions, be they climatic, economic or social. Buildings and cities traditionally evolved slowly so changes were implemented over decades. In recent decades' many new design innovations have been rushed to market without time to evaluate their success, in use, over time. Now we are experiencing new weather extremes on an almost annual basis it is essential that we develop processes not only to assess where traditional building elements and models do and do not fail and where innovations that fail to meet the requirements of the changing environment are caught well in time before they can do too much damage in the market places and across our cities and societies. This talk will outline the challenges involved and provide some evidence of how such evolutionary processes of failure detection and elimination might take place from Seville in Spain.

Austrian Pavillon in EXPO 2020, Dubai: A New Vernacular?

Peter Holzer and Georgios Gourlis

Ingenieurbüro P. Jung GmbH, Vienna

Austria's pavilion at EXPO 2020, Dubai is designed as a low-tech and eco-friendly building. The building offers comfortable indoor conditions with minimum use of mechanical climate control. The concept of natural air conditioning applies principles of traditional Arabic architecture and interprets them in a contemporary way; *Night ventilation* together with thermal mass, with the truncated cones serving as wind-towers, utilizing stack effect ventilation during the nights; *Subsoil cooling:* During the day, outdoor air for hygienic air quality is supplied via air ducts beneath the concrete floor, taken from the shady courtyard; *Comfort ventilation:* The outdoor air brought in via inlet vents and deliberately designed "Breeze Towers" which deliberately create a constant air movement within the pavilion in the range of up to 1 m/s; *Shading:* The queuing-zone in front of the building as well as the public courtyard will be shaded from plants and equipped with mist nozzles, offering adiabatic cooling together with the shadows from the plants; *Local and temporal active cooling* is supplied by means of a highly efficient solar-assisted chiller. The chiller supplies specialised "Breeze Towers", which combine the performance of displacement ventilation fan coils with the benefits of comfort ventilation and a *grid connected PV-system* delivers green electricity, not at least supporting the chiller.

Are Rating Systems Fit for Purpose at the extremes? (Presentation only)

Peter Hickson

President of the Australian Earth Building Association

Australia has been suffering from extreme heatwaves over the last decade with temperatures records being broken year on year. The death rates from heat stress related causes are rising also year on year. Many Australian homes are poorly designed for the climate and require high levels of air-conditioning to keep occupants thermal safe during periods of extreme hot or cold weather. I live in a mud brick home in which the high levels of thermal mass act to attenuate the thermal extremes during extreme weather events. In this presentation the thermal performance is used as a case study of how heavy weight mud brick construction works in high and low temperatures to ensure comfort for its occupants can remain thermally safe in it, even when the grid power fails or energy bills become unaffordable. Unfortunately, in Australia the mud brick construction industry is now being killed off by the NATHERS energy rating system that is designed to favour light weight and mechanically cooled homes. It is time we now ask whether, in light of more extreme climate and weather trends and events, current approaches to rating systems are now 'Fit for Purpose' in a warming climate.

Extreme Design: Lessons from Antarctica

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The warming global climate is triggering ever more extreme weather events with records being broken year on year for flooding, heat and cold waves and wind strengths. Consequently, more buildings are failing in the face of such weather events. In order to build structures that can withstand ever greater climate challenges in which people and populations can 'bounce forwards' to remain safe in them, even in worse weather conditions, we need to upgrade our approach to the climatic design of buildings around the world. A recent project to design a tent to stand for twelve months at Collins Bay, Antarctica, emphasised that it is difficult to approach more 'extreme design' without actually experiencing the extreme conditions they may be required to operate in. This paper outlines what was learnt in that project about designing for extremely cold and windy environments.

Lessons learnt were often unanticipated and included new insights into the form, materials, design, construction and siting of the tent at both its design, its fabrication and its building stages. This paper outlines the main steps in that design learning. The project clearly demonstrated the complexity of the issues involved in making sure the tent was optimally designed and built for and in its location, with a view to ensuring it would not fail in local conditions which include minus 300C during winter and locally recorded winds of up to 200pmh. It provides valuable lessons on the underlying process of how to design more generally for more extreme weather futures.

NON-ATTENDING AUTHORS

Evaluation of psychological and physiological response to transient comfort conditions in Singapore

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Microclimate has among further key factors a fundamental influence on how people occupy and use public spaces in dense urban environments. Comfort evaluation of outdoor spaces is essential since they accommodate daily pedestrian traffic and various outdoor activities, also they contribute largely to urban liveability and vitality.

In the wider context of adapting our cities to assure human comfort, the present study investigates individuals´ subjective and physiological responses to sudden and unexpected changes that urban microclimates generate.

The objective is to verify correspondences between physiological and psychological response to varying environmental condition in Singapore´s outdoor spaces, focusing on the transient conditions from outdoor to indoor (conditioned and non-conditioned), shaded and mechanically ventilated spaces.

Significant changes in thermal sensation votes were found when transiting between indoor (air conditioned) and outdoor spaces. Our results showed that exposure to high temperature causes thermal stress. Although the subjects expressed cool sensation when transiting from outdoor into indoor, such heat stress is not relieved by short-term exposure to cooler environment and will amplify the increase in hot sensation once the subjects were back into the outdoor space. In addition, thermal comfort under transient conditions is strongly affected by the sky condition and air temperature.

ENERGY GENERATED EXTERNAL ENVELOPE TOWARDS THE METHODOLOGY OF DEVELOPING THE PERFORMANCE OF THE EXTERNAL ENVELOPE TO ACTIVATE SOLAR ENERGY SYSTEMS

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The energy consumption in buildings is one of the most important issues in the 21st century. Most of the researches and recommendations focused on using the renewable energies and attempts to develop its technological systems, parallel in the same time with the technological development. Nowadays we can notice the need for making an integrated design for the external building envelope to build an energy generator external façade through an architectural vision.

The paper discusses the problem of the obvious gab between the architectural elements of the external building envelope and the technical elements of the solar energy systems, especially in the existing buildings which are to be supported by solar systems later, which it may not be acceptable to the architectural vision.

The paper aims to develop an applied methodology to improve the design efficiency of the PV systems to be integrated with the building elements as a tool to create a GENERATED PV/ARCHITECTURE building,

Vernacular houses: exemplars of survival and comfort in extremely hot and humid conditions

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With rapid urbanisation in the developing world, much of which is occurring in hot climates, methods of providing sustainable thermal comfort without resorting to energy intensive equipment are urgently required. In such climates, most urban buildings are dependent on electrical air-conditioners, leading to increased use of energy to maintain comfortable indoor conditions during the hot season. This results in more emissions of carbon dioxide, which contributes to global warming. As the climate gets warmer, the dependence on electrical air-conditioners increases to avoid the risk of overheating. In these regions, reductions or cutbacks in electrical power are predicted because of problems related to the production of electricity and overuse by consumers. Therefore, if for any reason the electricity fails, urban buildings become overheated, and under extreme conditions, uninhabitable. It is necessary to take steps to prepare for and adapt to such conditions. For centuries, before electric cooling systems were invented, traditional houses in the hot and humid regions of Jeddah were designed in such a way that the inhabitants were able to cope with extreme climatic conditions. These houses serve as exemplars to demonstrate how extreme temperatures could be managed in the absence of electrical power. But, are these past design solutions still sustainable in present-day environments? This article identifies the main vernacular strategies and technologies (i.e., natural ventilation, shading, thermal mass, material selection, etc.) that were used in the design of traditional housing in the hot, humid climate of Saudi Arabia. We investigate, through interviews, how they are perceived by their local users and stakeholders. This study was used to generate an understanding of how such technologies might be upgraded to help provide truly sustainable and comfortable buildings under extremely uncomfortable living conditions.

Thermal Comfort in Higher Educational Buildings: Different Classroom Types

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Thermal comfort in learning environments influences the students' attention, concentration and learning productivity. Due to the impact of the thermal environment on students' thermal comfort and consequently their productivity in line with the impact on energy consumption, this topic has attracted substantial attention among researchers in the recent years. This study aims to evaluate thermal comfort of the students in different classroom types in the UK higher learning environments. Thermal comfort zone, comfort temperature and thermal acceptance are evaluated under Free running, Cooling and Heating modes. Simultaneous environmental measurements and questionnaire survey were conducted in the classrooms under each mode. 2046 students participated in the surveys in a university building in Coventry, United Kingdom, between October 2017 and March 2018. Results present thermal comfort zone between 21°C and 25°C and comfort temperature of around 23°C in the classrooms under each operation mode. The research output helps to expand the existing environmental guidelines for higher educational buildings to have more reliable and energy efficient standards.

Monitoring the performance of a passive downdraught evaporative cooling (PDEC) system – a case study of a library in Saudi Arabia

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This paper presents field measurements and analysis from the performance monitoring of a Passive Downdraught Evaporative Cooling (PDEC) building in Saudi Arabia. Summer temperatures in Saudi Arabia frequently exceeding 45°C, and daytime relative humidities can be below 20% during the same period. The case study building, Dar Al-Rahmaniah, is a small public library located in the central region of Saudi Arabia. The library consists of three main parts, which include separate sections for men, women and children, and an auditorium. The men's section was chosen for the monitoring process as it represents the largest part of the library. Two PDEC towers are used to cool the large open space of the library. Central and leeward clerestory openings in the roof exhaust the stale air, allowing the evaporatively cooled air coming down the towers to circulate within the space. The primary aim of this study was to investigate the applicability and effectiveness of the PDEC system in the hot and arid climate of Saudi Arabia. For over 70 days during the summer of 2018, a range of data loggers were installed in the case study building to collect data. Different types of data loggers were used to record various parameters inside and outside the towers and the building, including external and internal dry-bulb temperatures, wet-bulb temperatures, relative humidity and external wind speed and wind directions. The case study provided detailed information about the performance of the PDEC tower in the climate of Saudi Arabia. The results indicated that PDEC Towers can achieve significant cooling for most of the time, but that their effectiveness was influenced by changes in wind direction and wind speed. Some reasons for this loss of effectiveness are discussed.

Field test of the performance of a double skinned ORV8 Tent Envelope

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More and more people globally are living in temporary structures as a result of catastrophic or systemic displacement of populations, as a result of climate change, wars and economic pressures. The need for more research on the cost and performance efficiency of tent materials and structures is clear but hindered the lack of precedents in the field. Little systematic research has been put into optimising tent designs for different climates and many new materials that may potentially be very effective in tents are not tested in relation to their performance as building materials. This paper describes first steps taken towards the development of an experiment evaluation of an innovative fabric, ORV8, in relation to its potential use in constructing a yurt like tent to be erected in the extremely cold and windy climate of Antarctica. The manufacturers of ORV8 were unwilling to support us in the larger scale manufacture of the material unless they could be certain that it would perform adequately thermally or structurally on site. To explore and test its performance, an experimental proto-tent was fabricated and then tested in a meat storage facility in Hull that is run continuously at around -200C. This paper reports on how the tent performed thermally during these exploratory tests and concludes with the lessons learn during the process.

Assessment of thermal overheating in free-running buildings in Cairo

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Assessing human health under climate change in hot climates is of particular importance in the Middle East. Cairo is one of those cities that have an estimated 2018 population as high as 13 million, with a metropolitan population of 21 million, which makes it the largest city in Africa and the Middle East. In and around Cairo, many of the summer seasonal deaths are blamed on human discomfort due to anthropogenic climate change. High urban population density, urban heat island effect, cramped living conditions including housing, schools and prisons are all reasons to the increase of heat-related health problems in Cairo. Therefore, this initial study investigates and maps overheating in free-running residential buildings in Cairo. The study follows a combined, monitoring and observational assessment of the 2015 heat wave (19-day event) in Egypt. Using surface urban heat island maps, representative urban areas were determined and field measurements were carried out to assess indoor air temperatures and relative humidity. This was followed by observational field visits and interaction with local citizens to document the impacts and adaptation measures corresponding to overheating. The paper provides insights on indoor human discomfort with a focus on physical and non-physical heat stress reasons during climate extremes. The study provides initial insights on thermal comfort that can prompt local professionals and governments to address overheating and thermal stress in free-running residential buildings.

Comfort at the Extremes: Energy, Economy and Climate

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