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OPINION

Innovate green building for urban heat mitigation and adaptation

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Urban heat, the combined effect of heatwaves and heat islands, affects numerous cities worldwide. Beyond severe environmental, economic, and social consequences, urban heat is the cause of excess disease and deaths. Urban heat is the most fatal weather-related phenomenon in many nations. Moreover, heatwaves and heat islands can potentially synergize [1], creating severe heat-related challenges for urban agglomerations and metropolitan areas. Urban heat will be more frequent, severe, and intense in the coming decades, especially in developing and expanding cities. Evidence further shows that heat stymies progress on all 17 Sustainable Development Goals [2]. The ageing trend in many urban populations compounds the risk of heat-related mortality and morbidity. Beating urban heat is a fundamental component of Sustainable Cities and Communities (Sustainable Development Goal 11) and Climate Action (Goal 13). However, so far, society has not been well prepared for urban heat, and limited actions have been carried out by governments and industry.

The building and construction sector must be at the forefront of change to deliver sustainable, resilient, liveable, safe, healthy and inclusive built environments. Over-dependence on concrete-cement-asphalt-based construction materials and compact landscapes enhances heat absorption and storage, while reducing heat dissipation and evapotranspiration. This leads to buildings and road patches being commonly identified as hot spots on heat maps. Conventional site planning and design fail to set heat adaptation as a design goal, significantly constraining the thermal usability of outdoor environments when heat surpasses a normal level [3]. Citizens are mostly forced to adapt indoors via air-conditioning systems, leading to an increase in building electricity consumption. Where the electricity is fossil-based, this can result in increased greenhouse gas emissions. Innovating and changing building and construction models, methods, and techniques is imperative to improve heat mitigation and adaptation capacity.

Green building is a prospective and transformative industry that aims to deliver environmentally responsible and resource-efficient built environments. Integration of heat-related goals and targets into green building design ensures resilience to extreme heat in terms of site quality, building resistance, and occupant well-being and productivity. The basic need is to expand green building goals and targets for microclimate regulation beyond the original expectations of energy consumption reduction, carbon emission reduction, and indoor environmental quality [4]. People-centric, heat-resilient cities of the future must include comfortable, safe, and healthy built environments for all, as well as convenient access to community services. There is a need to break down design goals and targets into different categories and priorities, including site planning and landscape design, building function and types, flow layout and organization, structural and physical environments, and security design.

Prioritizing cooling techniques is an emerging requirement for architects, designers, and engineers to realize zero-heat or microclimate-neutral buildings. Innovative materials with high albedo, high emittance, high permeability, urban greenery, blue infrastructure, shading strategies, and ventilation techniques have been developed for cooling purposes [5]. There has been extensive exploration of the regulation of physicochemical, morphological and structural properties of construction materials and techniques to maximize their cooling potential in different idealized climatic and urban development contexts. The key task now is to improve the applicability of these cooling techniques to real urban and building surfaces, their compatibility in satisfying multiple functions, and the avoidance of introducing unexpected consequences. One direction is to develop smart materials and devices with broad and universal application potentials for modern buildings. Another direction is to rethink the evolution of building surfaces, styles, and structures to overcome the limitations of additional weight, color, size, and form when accommodating more cooling techniques. The current intensification of urban heat is a significant event in the long history of urban design and architecture, which poses a serious threat to traditional approaches. Future construction cultures will need to be based on new paradigms that can enable citizens to survive heat challenges with minimal impacts. Compared to passive design techniques, air-conditioning systems have already been accepted as a new culture for temperature and humidity regulation. This is the most effective adaptation method for extreme heat events. However, the evolution of air-conditioning technology and usage culture continues, and a future development may focus on reducing the impacts of waste heat outdoors when cooling [6].

Strong heat exposure is a common feature of urban construction sites, making workers vulnerable. It is difficult to foster decent and safe jobs for laborers under severe heat stress, whose vulnerability is often compounded by low payments, imperfect security benefits, and ageing demographics, especially in underdeveloped and developing nations [7]. Shaping a no-heat-harm worksite by providing temporary shading, setting up cooling centers, and scheduling adaptive working hours are key elements of an approach for reducing on-site heat stress. Work clothes should be designed to improve body heat dissipation through cooling, ventilation, shading, and dehumidification. Intelligent detection systems (e.g. cameras and sensors) can be integrated in helmets and clothes to monitor body temperatures, send alert information, help site managers and laborers make informed decisions. Meanwhile, the application of digital twin technologies on smart construction sites can allow laborers to manage and perform non-contact tasks in real sites with strong heat challenges. Educational programs and appropriate insurance policies in relation to heat stress prevention are also needed to enhance employers, managers, and laborers' adaptative capacity.

There is also a need for a shift of focus towards buildings' operational performance. Temperature reduction capacity under intense heat should be a fundamental standard for evaluating operational performance. Building types, functions, morphologies, and climates are factors affecting operational performance; however, operational performance also interacts with socioeconomic characteristics in meeting comfort, productivity, health, and safety requirements. Reliance only on mitigation techniques cannot always limit temperature extremes to a normal level. Real-time heat monitoring systems and digital alerting and guidance devices are increasingly required for open spaces and buildings to detect heat signals and identify high-risk periods, locations, routes, and areas. Moreover, as the impacts of urban heat are dependent on meteorological and climatic conditions that can vary on short and long timescales, there is a need for smart responses to dynamic heat challenges on an hourly, daily, monthly, and seasonal basis.

Performance-centric mitigation and adaptation strategies propose higher and stronger requirements for maintenance than schemes certified only by design-and-construction credits. Water-driven strategies (e.g. greening, permeable materials, and water landscapes) cannot cool down without sufficient water replenishment. Vegetation cannot survive under extreme water deficit conditions. Regularly cleaning accumulated dust is a requirement for high reflectivity and emissivity of surface materials. A stable electricity supply is important to support occupants to endure abrupt extreme temperatures; therefore, the power grid should be examined and upgraded to prevent blackouts. Auxiliary and emergency power systems should be maintained to ensure control flexibility and supply stability when a heat-sensitive power generation system (e.g. hydropower) fails. Emergency power maintenance is also becoming increasingly important for ensuring supply robustness. More intense extreme heat in the future increases the possibility of exceeding the capacity of mitigation and adaptation systems developed in current, short-term, or medium-term scenarios. This highlights the importance of periodic post-occupancy assessment, thereby strengthening and improving mitigation and adaptation capacity to address evolving heat challenges. Electronic components and devices for heat information monitoring, processing, and transmission may fail owing to overheating, and auxiliary facilities for outdoor and indoor cooling may be out of order when the heat exceeds their design thresholds. Water deficit is a secondary challenge due to the co-occurrence of heat and drought [8], which limits the evaporative cooling potential. The development of post-heat recovery systems by restoring, repairing, and upgrading strategies and techniques that fail during heat events is a new qualification for green buildings.

The current and projected evolution of climate change and urbanization has led to a dynamic and increasingly rigorous transition toward heat resilience. Standards, regulations, models, and paradigms should be updated and renewed. Assessment standards should define heat-related goals, targets, indicators, and techniques. For instance, new buildings and constructions should be heat-island zero or negative compared with the original sites, while innovations should be able to enhance heat resilience prominently. A series of quantifiable indicators of technique application and performance assessment should be included in assessment standards [4]. Regulations are important for stipulating employment, materials, structures, devices, facilities, and management for mitigation and adaptation. Scientific models for heat-related information estimation and projection should be assembled, corrected, and downscaled to provide accurate performance analysis and support real-time assessment. Moreover, decision support tools and models should be developed to assist architects, designers, and engineers in making proper decisions regarding mitigation and adaptation [9]. This is important to close the knowledge gap in the transformation of the building and construction sector towards urban heat mitigation and adaptation.

References

1. Khosla R., Miranda N. D., Trotter P. A., Mazzone A., Renaldi R., McElroy C., et al. (2021). Cooling for sustainable development. Nature Sustainability, 4(3), 201–208.
2. Founda D., & Santamouris M. (2017). Synergies between Urban Heat Island and Heat Waves in Athens (Greece), during an extremely hot summer (2012). Scientific reports, 7(1), 10973. https://doi.org/10.1038/s41598-017-11407-6 PMID: 28887502
3. Huang B., Dong X., Tian Y., Yin M., Qiu Y., & He B. J. (2023). Experimental investigation of the thermal usability of outdoor environments in rideability, walkability, entertainmentability, exercisability and workability for urban heat mitigation, adaptation and governance. Natural Hazards, 1–30.
4. He B. J. (2019). Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building. Sustainable Cities and Society, 50, 101647. https://doi.org/10.1016/j.scs.2019.101647

5. Santamouris M., Ding L., Fiorito F., Oldfield P., Osmond P., Paolini R., et al. (2017). Passive and active cooling for the outdoor built environment–Analysis and assessment of the cooling potential of mitigation technologies using performance data from 220 large scale projects. Solar Energy, 154, 14–33.
6. Takane Y., Kikegawa Y., Hara M., & Grimmond C. S. B. (2019). Urban warming and future air-conditioning use in an Asian megacity: importance of positive feedback. npj Climate and Atmospheric Science, 2 (1), 39.
7. He B. J., Wang J., Zhu J., & Qi J. (2022). Beating the urban heat: Situation, background, impacts and the way forward in China. Renewable and Sustainable Energy Reviews, 161, 112350.
8. Lian X., Piao S., Chen A., Huntingford C., Fu B., Li L. Z., et al. (2021). Multifaceted characteristics of dryland aridity changes in a warming world. Nature Reviews Earth & Environment, 2(4), 232–250.
9. Qi J., Ding L., & Lim S. (2022). A decision-making framework to support urban heat mitigation by local governments. Resources, Conservation and Recycling, 184, 106420.