WATeRVASE: Wind-catching Adaptive Technology for a Roof-integrated Ventilation Aperture System and Evaporative-cooling

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Abstract

The WATeRVASE is a Wind-catching Adaptive Technology for a Roof-integrated Ventilation Aperture System and Evaporative-cooling. Prior research for the adaptive wind catcher technique demonstrates the effective multi-fin design composition for geometry shifting in response to wind directions and speeds (Aviv, Meggers 2018, 186-195; Aviv, Axel, 2017, 1123-1128). Other prior research demonstrates the effectiveness of superporous polyelectrolyte hydrogels for water sorption and diffusion (Smith, 2017, 2481-2488; Ida, 2018). Our team members have also developed a machine-learning platform for testing building technology prototypes for particular environmental conditions and building integration analyses (Smith, Lasch, 2016, 98-105). The new area of research combines the prior work of environmental systems, material science, and electrical and computer engineering for expanding the potential environmental variables that might be addressed simultaneously with the WATeRVASE. Human thermal comfort is one of the most significant challenges in hot-arid climate contexts due to energy-intensive building cooling needs, resulting in significant amounts of problematic carbon emissions. Existing experience has shown that passive cooling techniques with natural ventilation and evaporative-cooling provide excellent thermal comfort, together with very low energy consumption (Santamouris and Dionysia 2013, 74-79). The adaptive roof aperture is an advanced passive cooling system that responds to the external airflow thermodynamics by changing its membrane water sorption states to allow either downdraft airflow

(saturated top membrane) or nighttime radiation (open top with dry ventilation membrane). In this research, we are developing the adaptive roof aperture functions in the specific hot-arid climate location of Tucson, Arizona. The integration of the hydrogel membrane as an inner surface-lining of the wind-catcher will enable the control of moisture interface with airflow streams via hydro-pumps with sensors and actuation control, providing evaporative-cooling effects for the daytime downdraft system. Furthermore, the prototype incorporates a lyophilized hydrogel that provides for humidity sorption at the base of the cooling space for water recuperation. The hydrogel membrane may also provide daylighting and thermal conduction mitigation based on saturation states. The project will also explore the potential for rain-water harvesting with the roof-integrated aperture, which is especially necessary for drought-prone hot-arid contexts.

Keywords: Adaptive Windcatcher, Passive Cooling, Hydrogel Membranes, Machine-Learning, Natural Daylighting, Water Harvesting

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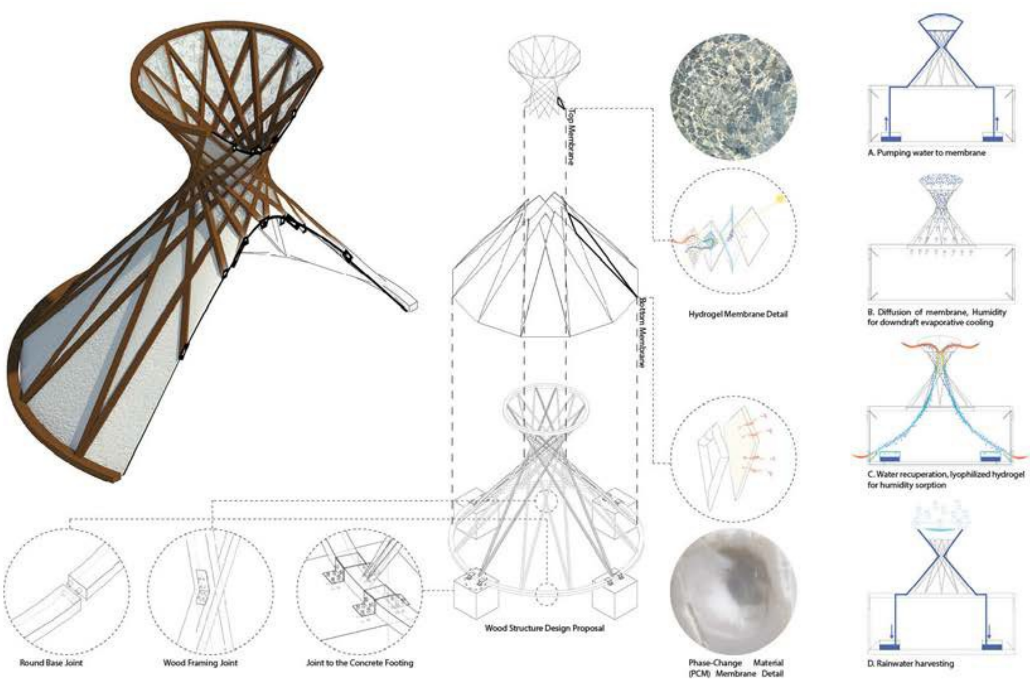

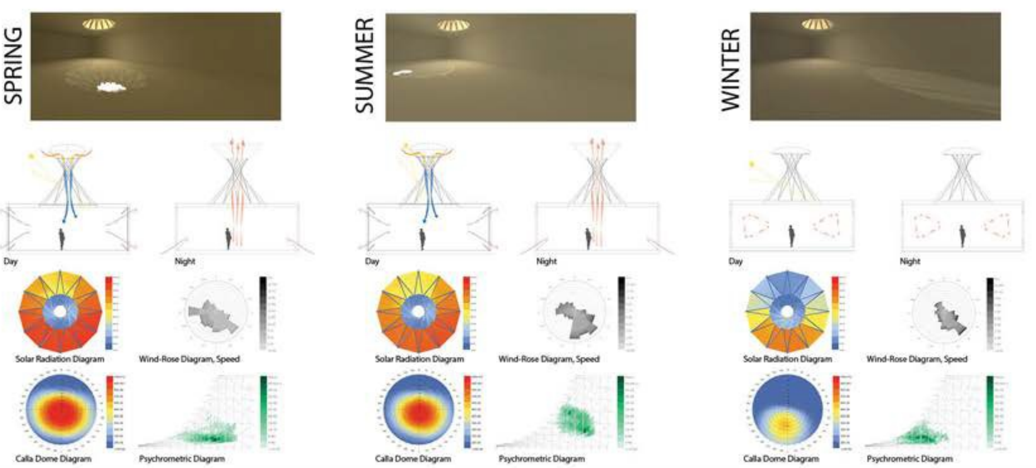

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The WATeRVASE is a Wind-catching Adaptive Technology for a Roof-integrated Ventilation Aperture System and Evaporative-cooling for hot-arid climate contexts. The example under study is being developed for the Sonoran Desert location of Tucson, Arizona. Prior research for the adaptive wind catcher technique developed by members of our research team demonstrates the effective multi-fin design composition for geometry shifting in response to wind directions and speeds (Aviv, Meggers 2018, 186-195; Aviv, Axel, 2017, 1123-1128). Other prior research by our team members demonstrates the effectiveness of super porous polyelectrolyte hydrogels for water sorption, diffusion, and daylighting control across large surface areas (Smith, 2017, 2481-2488; Ida, 2018). Both areas of prior work incorporate environmental sensing and actuation techniques for system responsiveness. Our team members have also developed a machine-learning platform for testing and developing building technology prototypes for particular environmental conditions and building integration analyses (Smith, Lasch, 2016, 98-105). The new area of research combines the prior work of environmental systems, material science, and electrical and computer engineering in a collaborative mode for expanding the potential environmental variables that might be addressed simultaneously with the WATeRVASE. Human thermal comfort is one of the most significant built environment design issues in extreme hot-arid climate contexts. Building energy consumption due to cooling loads in these climates is also contributing significant amounts of problematic carbon emissions to the environment, deeming passive cooling techniques a necessary approach in design. One of the oldest passive cooling systems that is still being used today is the wind-catcher (Jomehzadeh and et al., 2017).

Existing experience has shown that passive cooling through air-exchange dissipation techniques provides excellent thermal comfort and indoor air quality, together with very low energy consumption (Santamouris and Dionysia 2013, 74-79). The adaptive roof aperture is an advanced passive cooling system that responds to the external airflow thermodynamics by changing its geometry in order to maintain acceptable interior space temperatures. The passive cooling is accomplished through adjustments in the aperture fins to allow for either downdraft airflow (narrow top neck) or nighttime radiation (wide open top).

In this research project, we are developing the adaptive roof aperture functions with a specific hot-arid climate context so that multiple variables might be addressed. The integration of the hydrogel membrane as an inner surface-lining of the wind-catcher fins will enable the control of moisture interface with airflow streams, via hydro-pumps with sensors and actuation control providing evaporative-cooling effects for the daytime downdraft system. Furthermore, the prototype incorporates a lyophilized hydrogel that provides for humidity sorption at the base of the cooling space for water recuperation . When composited with glass or a translucent biopolymer fin substrate, the hydrogel membrane may also provide daylighting and thermal conduction mitigation based on saturation states. When the hydrogel membrane is saturated with water there is higher daylight transmission compared to the dry condition that condenses the polymer chains into a semi-opaque state. In both states, the hydrogel provides some amount of diffuse natural daylighting. The project will also explore the potential for rain-water harvesting with the roof-integrated aperture, which is especially necessary for drought-prone hot-arid contexts. The heavy monsoon rain season and winter rains provide opportunities for water harvesting with the large-scale adaptive aperture in an open position for gravity-feed collection.

The hydrogel membrane lining will enable large surface area exposure of a material condition that provides rapid saturation and retention of rainwater, helping to slow the rate of monsoon volume runoff during the water harvesting process. The work in-progress place-holders presented here will be further developed, including prototype development with the hydrogel and PCM materials, integration of sensing and actuation devices, the membrane sorption controls the relation to wind direction and temperature change. A full-scalemock-up with limited mechanical open-close aspects will be deployed for real-time in-situ testing for one month of Summer 2019.