Breathable Buildings:

Lightweight Dehumidification Envelope System for Social Housing Typologies in Hot-Humid Climates Incorporating Surplus Agricultural Materials

by

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ABSTRACT

In response to rising temperatures, humidity and reduced wind speed in hot humid urban conditions, agricultural byproducts can offer intelligent desiccant cooling alternatives to energy intensive conventional technologies. As a case study that is emblematic of global shifts in emerging energy consumption patterns, Mumbai is examined with respect to its critical housing shortage. In order to house its growing population, Mumbai is increasingly adopting concrete construction with energy intensive mechanical systems that have been associated with Western urban development practices for decades[1,2]. The thermal mass of concrete increases urban heat island effect and consequently building cooling loads. In addition, the adoption of universally accepted mechanical systems without sensitivity to local bioclimatic flows further exacerbates the growing energy consumption profiles of buildings. In hot humid climates, one of the priority challenges for energy reduction with respect to indoor thermal comfort is the sourcing of a viable means for passive dehumidification[3]. Most commercial desiccant materials such as silica gel, molecular sieves, calcium chloride and lithium chloride are not locally manufactured and contribute to indoor air quality issues because of toxicity.[3] Therefore, finding inexpensive locally sourced and environmentally safe alternatives to commercial desiccants is essential.

If used as a desiccant material, coconut husk an abundant agricultural byproduct in tropical countries, has the potential to provide economic and energy efficient dehumidification solutions at both the architectural and building systems scales in passive and active systems. India has an annual husk surplus of 86% (3.5 million tons)[4]. The embodied energy of this surplus, currently expelled in burning or composting, can be more efficiently diverted towards the production of energy efficient dehumidification

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[1] Emporis Research. "Commercial Real Estate Information and Construction Data", Internet: http://www.emporis.com Date last accessed, August 16, 2010.

[2] Municipal Corporation of Greater Mumbai, (2005). "Mumbai City Development Plan 2005-2025", Mumbai Metropolitan Region Development Authority, Mumbai.

[3] Rawangkul R., Khedari J. et al, "New Alternatives Using Natural Materials as Desiccant".

[4] Food and Agriculture Organization (2007), United Nations. "Chapter XV Coconut: Post harvest Operations."

strategies. Coconut husk, because of its excellent thermal[5], structural[6], adsorptive[3] and anti-fungal properties shows promise as a versatile material for building applications. In addition to its potential as a desiccant, it has excellent fire resistance properties[7], has the potential to prevent mold growth and can be manufactured into a building material that is highly durable but also easily biodegradable[8].

This thesis investigates the viability of coconut husk in mechanically assisted dehumidification strategies for social housing in Mumbai through the spatial implications of its adsorptive, structural and thermal properties. A literature review of current research on the potential of coconut husk along with TMY3 weather data serves as the foundation for a series of design experiments that combine energy simulations with parametric visualizations. Within the context of select housing typologies with highest potential for strategy deployment, these experiments provide a design framework for the potential implementation of light weight coconut husk desiccant systems. Cooling load calculations are used to estimate desiccant surface area[9], quantity of husk[9], and potential morphological configurations required for conditioning outdoor air to meet indoor thermal comfort requirements. Energy simulations are used to compare the energy consumption profile of a standard four-story building with that of a building-integrated dehumidification system incorporating coconut husk passive dehumidification, mechanically assisted ventilation and low thermal mass double skin envelopes. The results show that such strategies have the potential to simultaneously

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[5] Smith (2007). “Breathable Housing: Incorporation of Agricultural By-Products in Housing Systems for Tropical Climates.” CASE, Rensselaer Polytechnic Institute, New York, NY.

[6] van Dam Ph.D., J. E. G., M. J. A. van den Oever, et al. (2006). "Process for production of high density/high performance binderless boards from whole coconut husk. Part 2: Coconut husk morphology, composition and properties." Industrial Crops and Products 24: 96-104.

[7] SHR Timber Research cited by Snijder M.Sc., M. H. B., E. R. P. Keijser M.Sc., et al. (2005). Coir Based Building and Packaging Materials. Amsterdam, Common Fund for Commodities: 121.

[8] Ghosh P.K., Sarma U.S. et al (2006). “A Novel Method for Accelerated Composting of Coir Pith”, Cadila Pharmaceuticals Pvt. Ltd. Ahmedabad, India.

[9] Brown, G.Z., Reynolds, J.S. et al (1992). “Inside Out: Design Procedures for Passive Environmental Technologies.” John Wiley & Sons, Inc., New York.

yield economic benefits for the agricultural industry, reduce imports of building materials/products, and help alleviate resource depletion. There is relatively sparse data in this emerging research area on recharge requirements of systems incorporating natural desiccant materials. This could be a potential limitation on future applications within passive and/or mechanically assisted installations; continuing research in this area of inquiry, particularly with instrumented data from full scale demonstrations, is needed to inform the development of natural desiccant materials and hybrid systems within housing structures for hot-humid climate types.