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Hybrid Green Technologies for Retrofitting Heritage Buildings in North African Medinas: Combining Vernacular and High-tech Solutions for an Innovative Solar Powered Lighting System for Hammam Buildings

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Abstract

This paper details a newly developed prototype which combines three functions: day-lighting, solar powered LED lighting and natural ventilation for the public bathhouses (known as hammams) of the heritage cities of North Africa. The prototype was developed as a result of an extensive architectural survey of 67 surviving historic baths in North African cities, during which a common problem of poor natural lighting and ventilation as well as inadequate electric lighting was identified. Combining the vernacular element of hammam day-lighting with solar powered night-lighting, the prototype was developed between August 2012 and March 2013 as part of a research project funded by Manchester University. Tests have been carried out on the roof of two hammams located in Fez, Morocco: hammams Seffarine (currently being rehabilitated) and Moulay Idriss (functioning). Results show that the prototype dramatically improves the day-lighting qualities in the bathing spaces and provides for up to 8 hours of continuous night solar powered electric lighting. Positive feedback has been received from the users and the manager of hammam Moulay Idriss on demonstrating the prototype.

The paper argues that the combination of a vernacular element with an affordable high-tech solution results in an innovative hybrid system that is user friendly, and sensitive to heritage buildings. Such a solution can act as a "green catalyst" by its adoption in the 4000 traditional Moroccan hammams. As these hammams continue to provide a facility for the population living inside the medinas, the adoption of this design will not only contribute to reducing energy consumption and using renewable sources of energy but will also help to sustain a traditional social and cultural practice which has supported the health and well-being of the population for many centuries.

Keywords: Solar powered electric lighting; Day-lighting; Heritage building; Hybrid technology; Hammam; Fez.

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1. Introduction

The hammām is a distinctive building type in North African and Middle Eastern historic cities that has evolved from the small Roman Baths, or Balnéa tradition [1]. Although the transition from a Roman and Byzantine bathing tradition to an Islamic bathing institution is not clear, the role of the hammām in facilitating major ablutions (the washing of the whole body) necessary before the act of praying has resulted in the proliferation of this building type in the fabric of cities of the Islamic world, and within walking distance of small and large mosques [2] [3] [4]. In addition to providing a venue for health and cleanliness for Muslims, at a time when private baths were rare, hammāms also provided a space for gathering and socializing particularly for women. In the modern era, where bathrooms are common, the personal hygiene function of the hammām is no longer a priority, but the institution itself remains a highly attractive health-oriented social place, both for tourists and locals [5].

Although the tradition of going to the hammām is disappearing in Cairo, Syria, Lebanon and Palestine where a few historic hammāms are continuing to operate, the institution remains well anchored in the lifestyle of the population of the Maghreb countries [5] as hammām facilities are still being built in new residential areas. A survey of all the functioning historic hammāms of the North African Medinas of Cairo, Tripoli, Tunis, Algiers. Fez and Marrakech, was conducted by the first author between 2007 and 2010 revealed that several of these structures were being closed after having sustained themselves for many centuries (project funded by the Arts and Humanities Research Council in the UK) [5][6]. Their closure is due to increasing costs of water, electricity and fuel. Whereas traditionally these facilities were economically viable, relying on their own wells for water, recycled by-products and organic garbage for fuel in their furnaces and did not use much electricity, their connection to the municipal water system, changes made to their traditional furnaces and their reliance on electricity to light their spaces has resulted in high running costs causing the closure of many. Of all the countries of the Maghreb, Morocco presents the largest number of historic hammāms (mostly owned by the Ministry of Habous) that are still functioning today providing a much needed facility for the population living inside the Moroccan medinas [7][8]. Discussions with the head of the hammām managers corporation in Fez and in Marrakech in 2009 and 2010 indicated that most hammāms are currently struggling to sustain themselves as the cost of water, fuel and electricity have increased dramatically, making the business of running a hammām unsustainable after centuries of good operation [8].

It was estimated that in Morocco alone, there are 10 000 traditional hammāms and that each hammām uses, on average, 1.5 tons of wood and between 60 and 120 cubic meter of water per day [9]. Water and fuel constitute 75% of the expenditure, with the remaining quarter being linked to electricity consumption [9]. Bearing in mind that hammāms work late at night for men, the electric lighting is continuous from sunset until dawn. In addition, the electric lighting is on during the day because the vernacular day-lighting system which consists of roof piercings (oculus) covered by blown glass bells has been made redundant through poor maintenance and the non-availability of the glass bulbs.

This paper presents the development of an innovative prototype to address the lighting and ventilation problem of traditional hammām buildings. It first presents the vernacular day-lighting system. The design, construction and testing of the prototypes that combine the vernacular system with solar powered LED light are then explained followed by the results obtained after the installation of the prototypes on the roof of hammām Seffarine (under rehabilitation) and hammām Moulay Idriss (functioning) in Fez. The last section discusses how such a prototype can act as a green catalyst for a sustainable rehabilitation of historic hammāms.

2. The traditional natural lighting system in hammam buildings

The hammām buildings of North Africa heritage cities are hidden structures that are fully integrated in the urban fabric of their cities. They are surrounded by other buildings adjacent to their external walls, hence providing good insulation from outside temperature. Consequently natural light and ventilation of most spaces is only possible through the round piercings of their roof which consists of a composition of domes and vaults (figure1). These piercings are traditionally covered by blown glass bulbs and constitute an architectural feature that is unique to this building type. Commonly known in the Arabic language as little moons "*qamarriyats*" or little suns "*shamasiyyats*", these glass oculus vary in number and size and form intricate geometric patterns on the roof of the hammāms [2][3]. Their frequency and location on the roof allow for beams of sunlight to filter through the thick steam of the bathing spaces from different angles and at different times of the day, creating one of the unique sensual experiences of the traditional Islamic public bathing spaces (figures 1 and 2) [10] .

Figure 1: The roof of hammām Seffarine in Fez (Photo by Dr Magda Sibley)

The light quality provided by the roof piercing is just sufficient for visual comfort but does not result in a bright atmosphere. The piercings tend to concentrate on the central part of the spaces, leaving the peripheral spaces (where bathers normally sit) in a state of semi-obscurity (figure 2). The low level of light is culturally acceptable as it allows a degree of visual privacy and forms one of the experiential characteristics in hammāms [10]. It is important to take into account the perceptual needs and cultural background of the occupants when addressing the lighting [11]. Indeed, it has been frequently mentioned by hammām managers that the light should not be too bright.

In an extensive architectural and social survey of the still functioning historic hammāms of the North African medinas conducted by Dr Magda Sibley between 2007 and 2010 *(*funded by the EU and the Arts and Humanities Research Council in the UK) it became evident that the natural light qualities of the bathing spaces in all the visited and photographed hammāms of Cairo, Tripoli, Tunis, Algiers, Fez and Marrakech have been dramatically affected by the poor maintenance and/or the closure of these roof piercings resulting in the substitution of natural daylight with electric lighting [12]. It also became apparent that the know-how of producing the glass bulbs for the hammām roof piercings has disappeared

with the exception of two workshops in Syria, one in Damascus and the other near Aleppo. The loss of the traditional technique for the production of the blown glass hammam oculus in the whole region has resulted in the loss of the day-lighting qualities that are typical to the hammām buildings. This is further aggravated by the inadequate use of electric lighting, consisting of single incandescent bulbs or fluorescent lighting resulting in a poor atmosphere inside the spaces and higher electricity bills (figure 3).

Figure 2: The natural light quality in the hot room of a hammām in Damascus (left photo by Pascal Meunier) and in hammām Seffarine - Fez (right photo by Dr Magda Sibley)

Figure 3: The hot room of hammām Seffarine in Fez in 2006 when the roof openings were blocked (photo by Dr Magda Sibley)

3. Vernacular architecture and a high-tech solution: the development of a hybrid system

In the context of the EU funded Hammamed project [8][9] the collaboration between Dr Magda Sibley, the Habous and the architect responsible for the rehabilitation of hammām Seffarine [9] has provided the opportunity to make a number of recommendations for restoring the day-lighting qualities of the internal spaces. Under the University of Manchester *"Investing in Success*" scheme, funds were obtained in May 2012 to develop and test a hammam lighting prototype which combines the vernacular glass bulbs and a solar powered LED lighting system.

Glass bulb prototypes (figure 4) have been produced to specifically cover the openings on the roof of the hot room of hammām Seffarine. Six units were produced in August 2012 at the World of Glass workshop in St Helens (near Liverpool, UK) by two students from the Design Department at Manchester Metropolitan University. The glass bulb shape is formed as a hemisphere with a flange to aid fixing. A neoprene seal acts as a watertight barrier and absorbs any movement through thermal expansion.

The solar panel produces 18 Volt at 10 Watt and is used to charge a 12 Volt battery pack. Control logic turns the LED light on at a predetermined lighting level and a dc-dc converter maintains the voltage from the batteries to the LED bulb at 12 Volt even as the batteries discharge. The light is turned off when the batteries reach a certain level of exhaustion.

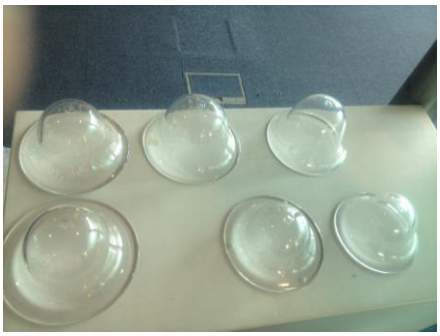

Figure 4: Blown glass bulbs produced at World of Glass in St Helens, UK photo by Dr. Magda Sibley)

4. Installation and discussion

Figure 5 shows the unit installed on the dome of hammām Seffarine. As can be seen from the right hand photograph, the LED light is suspended from a wooden former that rests on the opening. Prototypes of the bulb and the electronics have been made and successfully installed and tested in the hammām and figure 5 shows a unit operating at night. On some versions, the glass bulb can be removed for ventilation as well as for changing the light bulb when needed. This is aided by a pottery former that is inserted into the round piecing, providing a support on which the bulb rests.

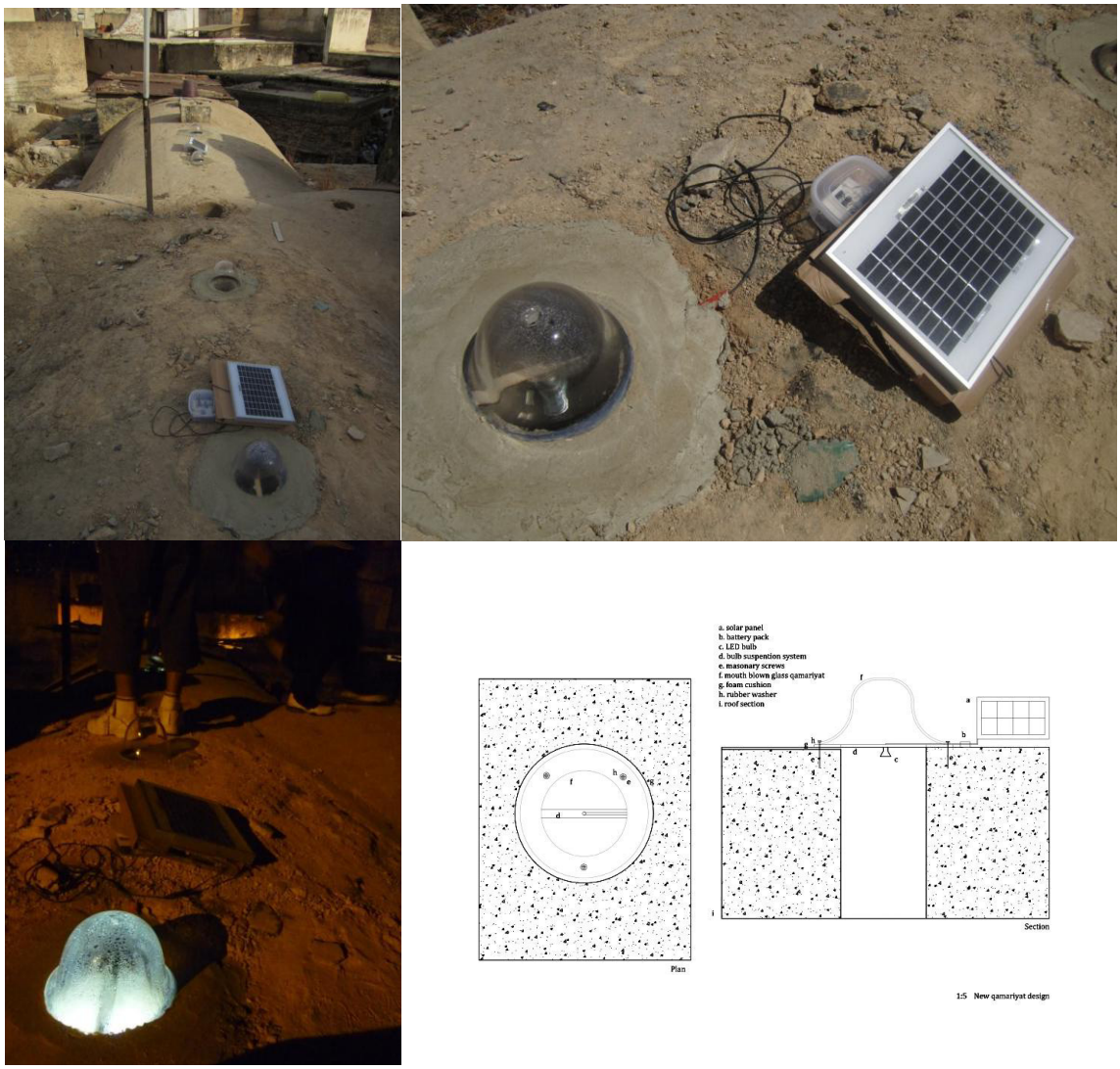

Figure 5: Day and night view of the glass bulbs installed on the roof on the hot room of hammām Seffarine in September 2012(top and bottom left) and plan and section of the glass bulb installaltion (bottom right)

The natural light effect inside the hot room was monitored during September and December 2012. A camera with a wide angle lens was placed on a tripod at the far end of the hot room of hammam Seffarine and the hot room space light qualities were photographed at 15 minutes intervals for a whole sunny day. A light meter was also used to measure the daylight at the same regular intervals. In January 2013, in order to increase the reflection of daylight from the glass bells and the surfaces of the clay potteries lining the roof openings, a reflective white paint was applied to both the external roof area surrounding the glass bulbs and the internal surfaces of the openings, resulting in an increased amount of daylight reflected into the spaces.

The solar energy powered lighting was integrated into every other natural lighting piercing, reinforcing the architectural qualities of the spaces at night in the same way as those obtained under daylight conditions. The solar light was also tested in January and March 2013 in the hot room of Hammām Moulay Idriss (functioning day and night) (figure 6).

In both case study hammāms a night-time illumination of between 7 and 8 hours was recorded. No measurements of the light were taken in hammām Moulay Idriss as this was not the object of the exercise. Instead comments were sought from users and the hammām owners. In all cases, the quality of the light was praised. In the case of hammām Moulay Idriss, comments were made by the bathers and the manager of the hammām as to the superior light quality obtained with the solar powered LED light as compared to the fluorescent tubes currently installed.

Figure 6: Installation on the roof of Hammām Moulay Idriss (left) and Hammām Seffarine (right). (Photo by Dr. Magda Sibley)

The different prototypes were also presented and discussed with the head of the hammām manager's corporation in Fez and the manager of Hammām Moulay Idriss, as well as the representatives from the Habous authorities and the contractor company in charge of the rehabilitation project. The concept and the prototype were very well received. Following this success, we are currently working to integrate all the elements of the prototype into one element and to commercialise the units and install them on hammām Seffarine as well as other hammāms in the medina of Fez. It is hoped that this will act as a catalyst for the repair of all the hammām roofs and the integration of a hybrid renewable energy installation. The next stage of the work is to examine the traditional furnace system to increase its efficiency and to reduce water usage and waste. In this way we hope to reduce the number of hammāms closing, because of high utility costs, and provide a sensitive approach to retrofitting this heritage building for energy efficiency, low running and maintenance cost so that it sustains itself well into the 21st century.

5. Conclusion

This paper has demonstrated the need to adopt an integrated approach when dealing with the rehabilitation of a heritage building such as the hammām. The combination of the vernacular natural lighting system, (specific to this building type) and a high-tech small scale solar powered electric lighting system allowed the development of a sensitive and non-intrusive solution. A number of prototypes have been tested and discussed with key stakeholders in order to finalise an optimal design that will not only improve day-lighting inside the bathing spaces of the many historic hammāms in the Moroccan and North African medinas but will also provide free electricity for night lighting of these buildings which usually operate until dawn. Unlike other systems, which tend to produce electricity with large solar panels, this innovative system relies on small panels that are affordable, transportable, moveable and replaceable.

A spin-out company under the name "HiSolar" has been formed and the prototype is being finalised and will be used for the repair of the electric and lighting system of hammām Seffarine in Fez. It will provide a sustainable and affordable environmentally friendly solution that can be adopted in an incremental fashion in all the historic and contemporary hammāms of Morocco and North Africa.

References

[1] Yegul F. *Bathing in the Roman World*. New York: Cambridge University Press, 2010.
[2] Dow M. *The Islamic Baths of Palestine*. Jerusalem: The British School of Archaeology in Jerusalem; 1992.
[3] Ecochard M. Le Cœur C. *Les Bains de Damas I and II*. Bierut: Institut Français de Damas, 1942, 1943.
[4] Sibley-Behloul M. Rehabilitating Hammam Seffarine in Fez. In: Dumreicher H, Levine RS, Sibley-Behloul M, editors. *Hammam Rehabilitation Reader*. Vienna: Sinderzahl Verlag, 2012. p.145-167.
[5] Sibley M, guest editor. Traditional Spas/Hammams in the Mediterranean: Rediscovering a Forgotten Heritage.*International Journal of Architectural Research, Archnet–IJAR*. 2008; **2**; Issue3.
[6] Destino T, Sibley-Behloul M. The Hammam Living Traditions. In: Dumreicher H, Levine RS, Sibley-Behloul M, editors. *Hammam Rehabilitation Reader*. Vienna: Sinderzahl Verlag, 2012. p 49-67.
[7] Sibley M. The historic hammams of Damascus and Fez: Lessons of Sustainability and Future Development. In: Weber, W, Yannas S, editors. "*Clever Design and Affordable Comfort: A challenge for low energy architecture and urban planning"* Proceedings of the 23rd International Conference on Passive Low Energy Architecture: Geneva: 2006; **1**; p 81-6.
[8] Dumreicher H, Levine RS, Sibley-Behloul M, editors. *Hammam Rehabilitation Reader*. Vienna: Sinderzahl Verlag.
[9] Martin AS, 10 000 hammam traditionnels au Maroc: *La vie economique* 21 October 2011.
[10] Tsikaloudaki K, Cocen ON, Tasopoulou K and Milonas I. Daylighting in historic bathhouses: the case of Ottoman hamams. *METU JFA 2013*; **1**: p 45-55.
[11] Belakhal A, Tabet Aoul K , Bennadji A. Sun lighting and day lighting strategies in the traditional urban spaces and buildings of hot arid regions. *Renewable Energy* 2004; **29**, p 687-702.
[12] Sibley M, Jackson I The architecture of Islamic public baths of North Africa and the Middle East. *Architectural Research Quarterly* 2012; **16**; Issue 2:p 155-170.