"Mushrabiyya" Patterns and Parameters: An Experimental Analysis For Daylighting Performance

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1. Introduction

There are some main approaches for architects towards traditional architecture and its relevance to contemporary architecture; complete rejection as architecture should be the product of our time and circumstances, complete acceptance, in fear of imitation of western architecture and losing our heritage , considering contemporary architecture as a continuation of traditional architecture, and the use of elements of traditional architecture in the design of new buildings especially vernacular elements that proved efficient in terms of climatic and daylight control like the design of openings. One significant type of Traditional openings is the Mushrabiyya which is a culturally appropriate feature that can fit easily in modern conditions and contexts and respond to cotemporary needs. It is a bow window that has no glass, being fitted with timber grilles and shutters permitting a cooling breeze to enter the building in hot climatic conditions. The design of the "mushrabiyya" can be purposely created in adaptable designs in order to adjust the amount of desired light and air penetrating into the interior space moreover it is an element of cultural continuity and identity.
"Mushrabiyya" serves to reduce energy consumption of active systems by decreasing the thermal load due to sunlight; however the problem of shading devices is that despite its environmental benefits, it decreases the amount of natural light entering a space and thus increased consumption of energy through artificial lighting systems. There is a need to increase the performance of the "mushrabiyya" in terms of daylight penetration. In this paper, "mushrabiyya" is tested in terms of; the impact of its being made of different materials, if amount of daylight penetration can be controlled through varying sizes of openings, and whether its performance would be improved through the use of reflecting surface so as to increase the natural light in areas characterized with considerable depth.

2. "Mushrabiyya" Concept and Mechanism

The origin of the word "mushrabiyya" is derived from an Arabic word that means drinking area or place where small water jars were placed in it to be cooled by the air movement effect. Despite this concept, it became an important feature in Islamic buildings as a kind of screen window that symbolized the privacy required by the Arab Muslim society and as it offered filtration of daylight and provided a convenient cooling effect for hot arid climate. Figure 1

Figure1: A traditional design of "mushrabiyya" adapted to adjust the amount of desired light and air penetrating into the interior space.

2.1"Mushrabiyya" Configuration and Components

The expression of the "mushrabiyya" changed a lot over time and took different forms, the most popular of which is the protruding bay window fitted with timber panels composed of lathe fashioned wooden balusters creating an overall pattern of lattice work arranged at specific regular intervals, with various geometric designs, it is the sizes of the interstices (the spaces between adjacent balusters) and the diameter of the balusters that are adjusted. Although this feature identified a previous era, there has been a revival in its use in modern times due to its environmental efficiency in attaining comfort within indoor spaces. Figure 2 .

Figure2: The most popular form of "mushrabiyya" still in use in contemporary architecture.

There are different designs for the "mushrabiyya" but the most popular one consists of two main parts: the lower part which is characterized by the narrow size of the interstices, and contrary the upper part is characterized by a larger size of them, however sometimes this part could be at the same surface of the wall with an external light shelf. Figure 3.

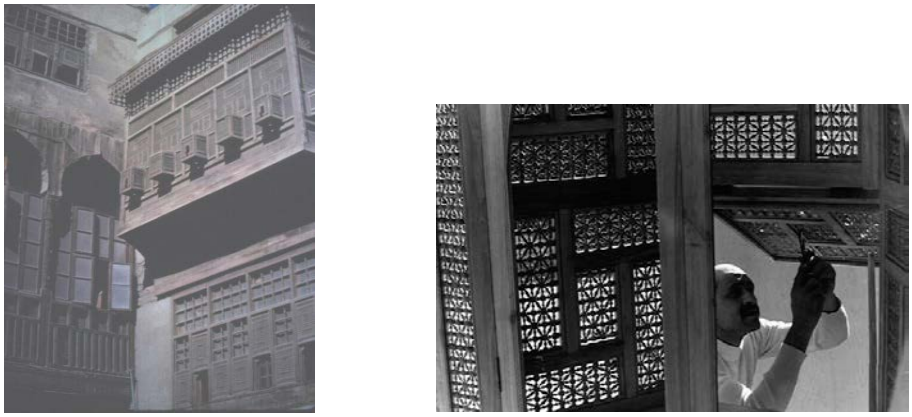

Figure3: "Mushrabiyya" as a fixed and operable opening.

2.2 "Mushrabiyya" Operation and Functions

According to the configuration and components of the "mushrabiyya", it proved, in terms of operation, three main functions: Daylighting control, thermal control and social privacy. "Mushrabiyya is a fixed shading device in the form of a bay window or an ordinary plane one with some operable panels. The sizes of the interstices and the balusters of a mushrabiyya placed in an opening are adjusted to intercept direct solar radiation this requires a lattice with small interstices. [1] The turned section of the mushrabiyya softened the glare of the sun and decreased the intensity of light as it penetrated into the room. Porous earthen bottles were placed in the mashrabiyya in order to be exposed to a current of air to cool water by evaporation.[3] Moreover, , it provides a view for the women, but at the same time it secluded them from any by-passer. Figure 4

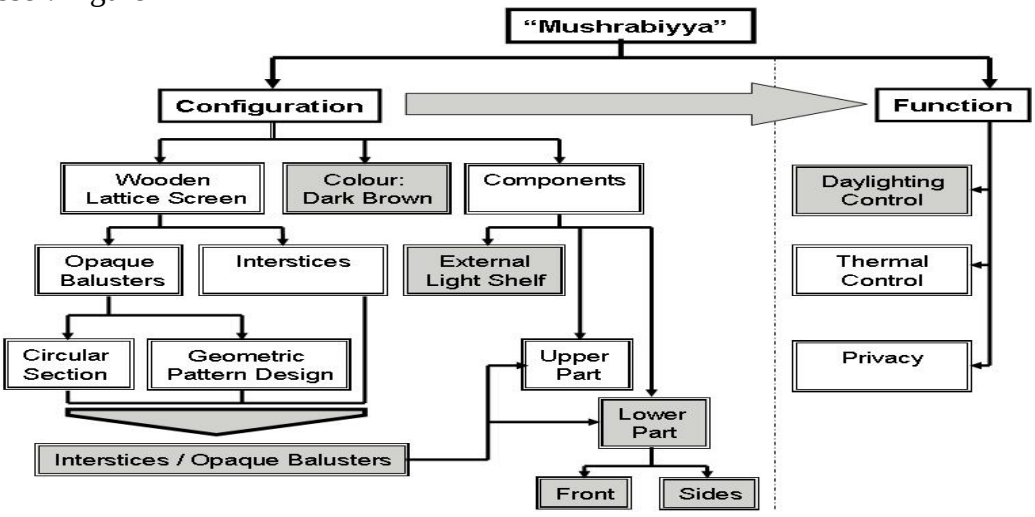

Figure4: Diagram showing the details of and the relations between "mushrabiyya's" configuration and function, the highlighted parts are those pointed out in the paper

3. "Mushrabiyya": Experimental Evaluation for Daylighting Performance

Physical scale modelling is the method used to analyse the performance characteristics of daylighting within an indoor space having a "mushrabiyya" for an opening. This method is considered as one of the few means that could judge the qualitative aspects of daylighting accurately. Moreover, this method could provide photographic records to the quality of daylight similar to the one inside the real building. [2] The experimental evaluation of daylighting performance consists of a group of tests -under a real sky- that concentrate on the effect of "mushrabiyya" configuration and components , as well as daylighting techniques on natural light penetration and distribution within the model. The tests could be considered as a comparative analytical study between different parameters in order to reach some accurate results.

a. Testing model scale (Reference model): The level of data required and the evaluation techniques used dictate the scale of the reference daylighting model. A large scale model 1: 5 is constructed to analyze the penetration of natural light, Figure 5.

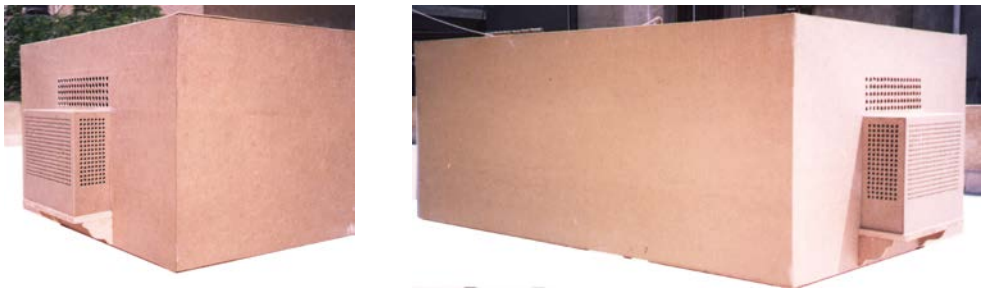

Figure5: The 1:5 scale reference daylighting model

The reference model is used to evaluate the performance of the various designs of the "mushrabiyya". It is worth noticing that there is an infinite number of assumptions for each parameter of the reference testing model that could lead to an infinite number of daylighting performance results. Therefore, some of these design assumptions have been chosen as follows, Figure 6:

- Indoor testing model dimensions: 5.00m * 8.00m - Height :3.20m
- Internal surfaces reflectance: The reflectivity of the materials used in the model has been approximately defined by measuring the ratio of the reflected light to the incident light (This method is accurate to within ± 10%) [2]
  - Walls : White 83%
  - Ceiling : White 83%
  - Floor: Medium brown 38%

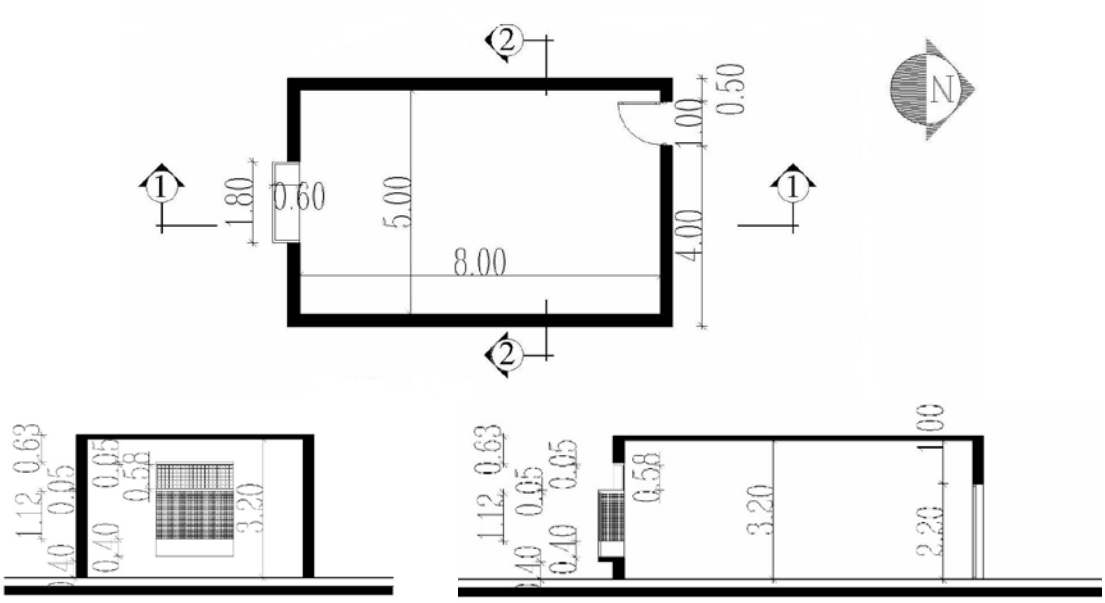

Figure 6: Plan and cross-sections of the reference model

- "Mushrabiyya" configuration: The opening of the model is made of a medium brown (Reflectance: 38%) wooden lattice composed of balusters that are rectangular in section (The traditional circular section is overlooked in the model for simplicity) and arranged at specific regular interstices.
- "Mushrabiyya" components:
  - Dimensions:
    - Lower part: 1.80m * 1.57m – Windowsill: 0.50m
    - Upper part: 1.80m * 0.63m
    - External extended light shelf: 0.60m
  - Interstices/Opaque Balusters Ratio:
    - Lower part(Front and sides): 55%
    - Upper part: 70%
  - Orientation: South

b. <u>Photometric Measurements:</u> The photometric evaluation requires the measurement of the absolute illuminance inside the model using a light meter. The light meter consists of two parts, first part is the proper meter where the illuminance data can be read and the second part is the light detector which is placed inside the model taking into consideration the prevention of any leak of light.[4] The establishment of the pattern of illuminance measurements in the testing models consists of the following:
   - Working plane height : 0.90m
   - Measurement grid: 2.00m spacing in both directions (Nine measurement points), Figure 7.

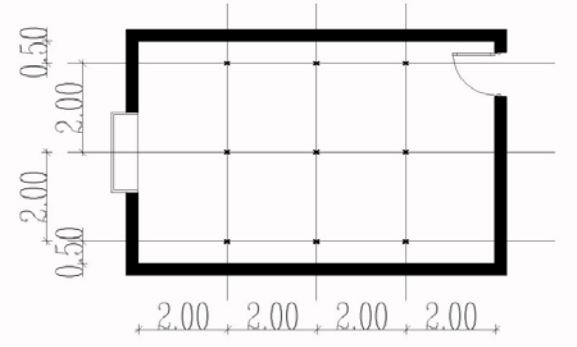

Figure 7: Measurement grid.

c. Photometric Testing Evaluation: The photometric Testing has been conducted under the real sky; in addition ground reflectivity surrounding the testing model has been recorded.
   - Latitude: 30° - Longitude: 31°
   - Sky condition: Clear sky with sunshine
   - Season and time of measurements : Summer -12 Noon
   - Ground reflectivity: 26%

The comparative analytical study for the performance of daylighting between the reference testing model and the changed parameter of the "mushrabiyya" consists of three groups of tests: First group focused on the ratio of interstices to the opaque balusters, second focused on the change of color of the "mushrabiyya" while the third focused on the effect of using daylighting systems. The tests' results will concentrate on the photometric measurement results of three reference points located on the grid line at the mid-width of "mushrabiyya": First point is the nearest to it, second one is situated at the middle of the model while the third is situated at the farthest end of it which indicates the penetration of natural light.

3.1 Interstices/Opaque Balusters Ratio

First group of tests concentrates on increasing the size of the interstices in the lower part to be similar to the upper one (70 %). The test consists of two testing models , in the first, only the size of the interstices at the front element has been enlarged, and in the second, only the size of the sides interstices has been enlarged, figure 8.

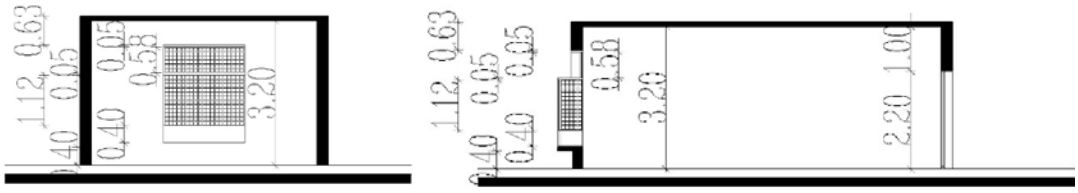

Figure 8: (Left) Only the size of the interstices at the front element has been enlarged ,(Right) only the size of the sides has been enlarged.

- Test Result: At the farthest end of the model (Third reference point) the illuminance has increased by an amount of 42% when the interstices sizes at the sides has increased, however in the case of changing the sizes at the front element of the "mushrabiyya" the illuminance has increased by 62% which means that the penetration has improved. On the other hand, in the two cases, the illuminance, has slightly changed (< 10%) near the "mushrabiyya" and at the middle of the model (First and second reference points).Figure 9.

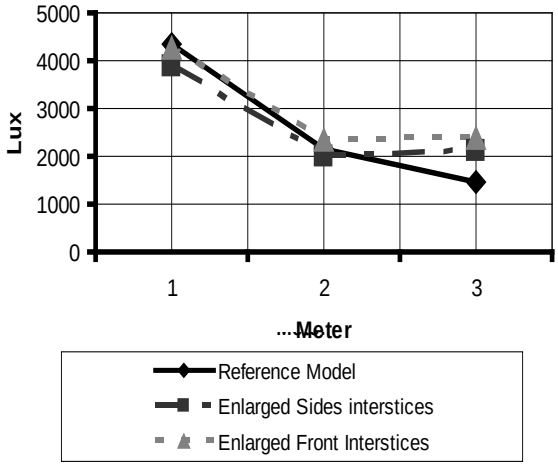

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Figure9. (Left) Photometric measurements results of the reference models and the two cases of enlarging the sides and the front elements of the "mushrabiyya" lower part. (Right) Photographic record inside the model in the case of enlarging the sides.

3.2 Change in "Mushrabiyya" Colour

The colour of the "mushrabiyya" has been changed to white colour with 80% reflectivity.

- Test Result: In this test, there is a big change in the amount of the illuminance at the three reference points when the medium brown colour of the "mushrabiyya" of the reference case has been replaced by a white one. The illuminance has increased by an amount of 70% near the "mushrabiyya" and at the middle of the model, while at the farthest end of the model the illuminance has increased by an amount of 50%. Figure:10.

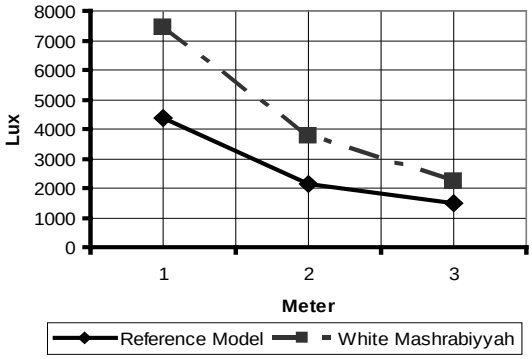


Figure 10: (Right) Photometric measurement results of the reference model in the case of changing the colour of the "mushrabiyya". (Left) External photograph of the case.

3.3 Daylighting Systems

The idea of adding daylighting systems to the components of the "mushrabiyya" affect and improve the penetration of natural light deep into the space without getting any effect on the special character of the "mushrabiyya". This group of tests concentrated only on 2 types of daylighting systems; the first one is a mirror added to the upper surface of the "mushrabiyya" light shelf (90% reflectivity), while the second one is a reflector positioned internally. Figure 11

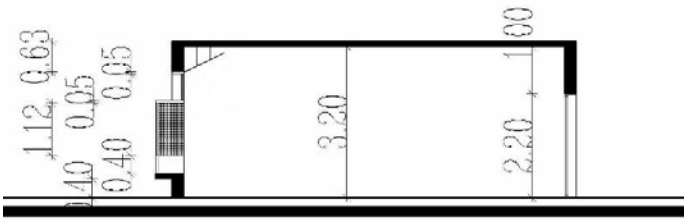
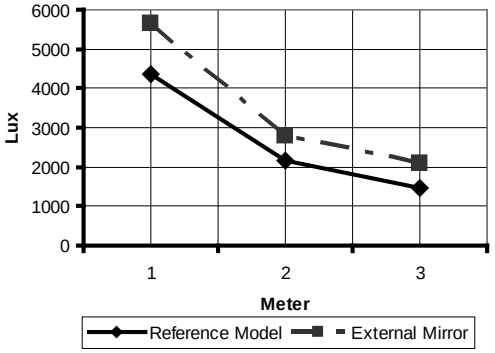


Figure 11: Section of the reference model showing the mounting of the internal reflector.

- "Mushrabiyya" light Shelf – Test Result: The illuminance has increased along the grid by the same amount (30%) in front and at the middle of the model while at the farthest end of the model the penetration has been improved as the illuminance has increased by 43%. Figure 12



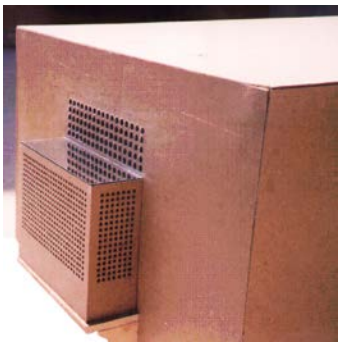


Figure 12: (Right) Photometric measurement results of the reference models in the case of adding a mirror to the upper part of "mushrabiyya" light shelf. (Left) External photograph of the case.

- Internal Reflector – Test Result: The illuminance has increased along the grid line especially at the farthest end of the space (third reference point) by an amount of 60%, while near the "mushrabiyya" and at the middle of the model the amount of illuminance has increased by an average amount of 50%, figures 12, 13.

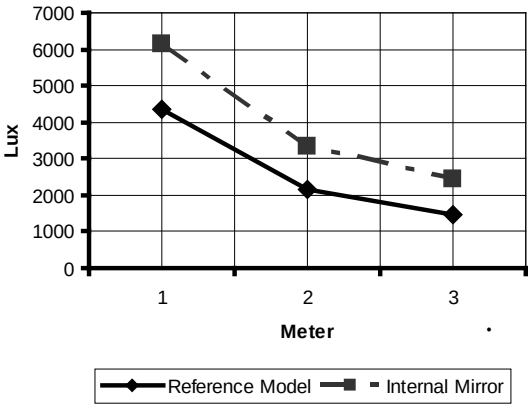


Figure13: (Right) Photometric measurement results of the reference model in the case of adding an internal reflector, (Left) Internal photograph of the case.

As general results, and from the comparative analysis, the natural light penetration could be improved – especially at the farthest end of the space – by changing some parameters of the "mushrabiyya": the careful distribution of the interstices to the balusters ratio on the upper part and lower part of the "mushrabiyya" improved natural light penetration by an average of 60%, and in the case of using light colour and adding the techniques of daylighting systems, natural light penetration improved by an average of 50%, which represent a very high percentage that can make a great difference in daylighting performance. Other properties may also be varied and experimented to achieve desirable performance of daylighting within an indoor space having a "mushrabiyya" for a window.

Conclusion

In recent years there have emerged architects who are seeking localism in their own way of working. Mushrabiyya is a significant element in vernacular architecture which is functionally and climatically sound despite its poor daylight deep penetration. In this paper, Mushrabiya was tested through varying of materials, sizes of interstices on its front and side elements one at a time, change in colour and using reflecting surface on both the light shelf and the interior. The results demonstrated accentuates the fact that the performance of daylighting could be improved through a careful and knowledgeable design.. While maintaining the integrity of mashrabiyya as an important local vernacular feature, we can benefit from its many social and climatic functions and improve its performance in terms of daylighting penetration through simple techniques which was considered the main drawback in the way of contemporary use of this feature.

References

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[3] Fathy, Hassan, Natural Energy and Vernacular Architecture, the University of Chicago Press, 1986.

[4] Gregg D. Ander, FAIA – Daylighting Performance and Design, Second Edition – John Wiley & Sons, Inc. – Canada (2003).