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An observation of shading devices in urban residential buildings in Daun Penh district, Phnom Penh: A study across architectural periods

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Abstract: There has been a marked increase in the pace of building construction in Phnom Penh, especially residential buildings. As reported by the World Bank, by 2050, about 36% of Cambodians will be living in urban settings. Over time, most building designs incorporated mechanical cooling systems in their building plans to create a comfortable indoor environment, which has led to an ever-increasing rate of energy consumption and thus global warming. In Phnom Penh's hot-humid tropical urban environment, shading devices are commonly used in building façade design to improve indoor environmental quality by using double façade or shading devices. In this study, the characteristics and development of shading devices in urban residential buildings in Daun Penh, Phnom Penh, are investigated with respect to different architectural periods. This research combines field observations, visual documentations, and architectural analysis techniques to determine the typical shading devices used on the facade. The analysis is performed based on the relationship between (1) the orientation of the building and (2) the facade design. The research aims to investigate the shading types used by 240 residential buildings through different periods and in four (N-S, E-W) oriented facades to learn how the design approaches have been practiced and improved to create quality indoor environments, energy efficiency, and thermal performance. From this study, it is found that most residential buildings designed during the French colonial era (1863-1953), New Khmer Architecture era (1953-1975), and recent times (2000s-present) focused on passive design approaches through the use of balconies (49%), horizontal louvers and deep verandas (15%), egg crates (12%), overhangs (8%), and vertical fins (1%). This research contributes to a better understanding of the different typologies of shading devices in improving the thermal performance of buildings and provides insights for passive design strategies in tropical urban contexts.

Keywords: shading device, residential building, architectural periods, tropical climate, Phnom Penh

1. INTRODUCTION

Tropical urban residential buildings are highly influenced by solar radiation and heat gain; therefore, shading devices are essential for enhancing thermal performance and reducing energy consumption. Climate responsive design is particularly important in tropical regions such as Cambodia, where environmental conditions strongly affect building performance [1,2]. The urban fabric of Phnom Penh reflects distinct stages of architectural evolution, including the French

colonial era (1863- 1953), New Khmer Architecture period (1953-1975), and contemporary developments (2000s - present). Each period exhibits unique façade characteristics and shading designs [3,4]. During the colonial period, passive design features such as deep verandas, balconies, and shutters, largely inspired by European architecture were widely implemented [5]. In the New Khmer Architecture era, modernist concepts were blended with traditional Khmer design, resulting in the utilization of systematic shading devices as fundamental passive solutions. These include

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overhangs, horizontal louvers, vertical fins, and egg-crate forms [6,7,8]. Such approaches were influenced by modernist ideas, notably those of Le Corbusier, particularly his concept of the *brise-soleil* for controlling solar heat gain and glare in tropical climates [9]. Since the early 2000s, rapid urbanization in Phnom Penh has led to significant changes in building façades, especially in the city center [10]. Contemporary designs increasingly incorporate energy-efficient materials and advanced shading systems, such as metal louvers, perforated screens, and dynamic façades [11]. Previous studies have shown that well-designed external shading devices can significantly reduce cooling loads in tropical housing by minimizing solar gain and while promoting natural ventilation [1,8,12]. Despite their importance, there is limited empirical evidence on shading devices in Phnom Penh. Article [8] studied about the shading device in Phnom Penh on general buildings in New Khmer architecture period and documented on some shading devices already. To address this gap, this study conducts observations of residential and commercial areas in Daun Penh district, Phnom Penh, Cambodia. It examines how shading devices have evolved across different architectural periods, focusing their types, materials, and relationships with building orientation and façade design.

This study aims to investigate how shading typologies related architecture period and orientation. In this article will describe how to collect data in field observation, the procedure of shading device typologies documentation and discuss the result in the final part. It will focus on how shading devices have changed from different architectural periods, including their types and materials used, and their relationship to building orientations and facades.

2. METHODOLOGY

This study employed an observational survey to document shading device typologies across selected residential buildings within Daun Penh district of Phnom Penh, applying systematic sampling strategy to select the buildings and using an observation sheet to record the information of buildings and shading devices. A total of 240 buildings were observed, four sample street within three zone of Daun Penh district were selected. A coding system was developed for both buildings and shading typologies to compare and analyze between all observation buildings. The results indicate the numerical of existing shading devices used in observation areas. Chi-square test was adopted to find the relationship between shading typologies and orientation to examine which typology is commonly used in which orientation and how these shadings responded to its function.

2.1 Data Collection

This study employs field observations to investigate exterior shading devices on residential buildings in Daun Penh district, Phnom Penh, Cambodia. The district was deliberately selected because it reflects the major stages of Phnom Penh's architectural evolution, ranging from the French colonial period and the New Khmer architecture era to contemporary developments. Owing to its high density of residential buildings and the continuous transformation of façades, the area provides an appropriate context for examining exterior shading devices. To ensure a systematic and comparative analysis, the study area was divided into three zones based on dominant architectural periods and urban characteristics [13]. This zoning framework enables the identification of morphological and contextual differences in shading practices across various stages of urban development. Figure 1 illustrates the location and dominant characteristics of the three study zones within the Daun Penh district.

This zoning framework allows the identification of morphological and current differences in shading practices across different stages of urban development.

- Zone A: Colonial core zone (Wat Phnom, River side quay), includes Sangkat Wat Phnom and Sangkat Shras Chork.
- Zone B: Modernist core zone (near Phsar Kandal and Phsar Thmey), includes Sangkat Phsar Kandal I-II, Sangkat Phsar Thmey I-II, and Sangkat Phsar Chas.
- Zone C: Commercial transition zone (Preah Sisowath high school area), includes Sangkat Phsar Thmey III, Sangkat Boeung Rang, Sangkat Chey Jonneas, and Sangkat Chaktokmuk.

Legend Notes

- Zone A
- Zone B
- Zone C
- Observed street
- Total observation buildings = 240

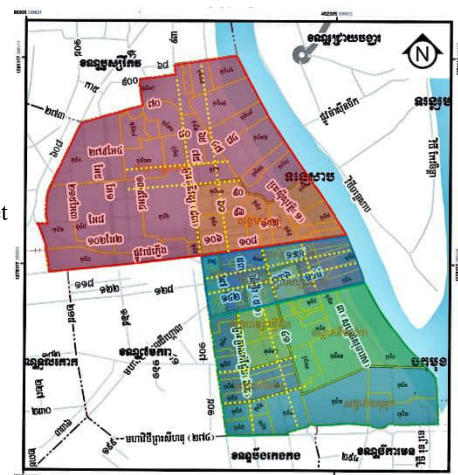


Fig. 1. Zoning map of residential building observation in Daun Penh district, Phnom Penh, Cambodia

Four sample streets were selected within each zone to ensure representation of both north-south and east-west orientations, thereby capturing typical urban conditions. The sample buildings have been systematically identified based on

interval sampling where every third ($k=3$) building is chosen on the chosen streets, starting from a certain initial point [13,14,15]. 80 buildings per zone were included, based on specific criteria such as residential function, building façade, and the presence of shading devices. Data collection was conducted using a structured observation form to ensure consistency reproducibility. The recorded parameters included building code, street address, building typology, orientation, construction period, shading device type, material, and geometric configuration. There are 240 buildings were observed, comprising apartments (9%), shophouses/link-houses (85%), and villas (6%).

2.2 Typology Procedure

The typology of shading devices was established based on multi-criteria classification approach, including architectural period, orientation, and geometry of shading. Shading devices were first identified based on the architectural evolution, this procedure allowing the study to understand shading strategies to specific architectural periods and design contexts. In case, the building was built in period X and shading was adapted later in period Y, we count this shading typology as built in period Y. Secondly, the building's direction is also identified because the solar radiation is a key factor influencing its effectiveness. Thirdly, geometrical patterns of horizontal, vertical, or combination shading along with the materials used for their realization have also been considered, providing various typological classifications. However, if the building was built with a mix shading device, we count the largest coverage area and the most repeated element as the shading typology.

To support systematic analysis, a coding system was developed for both building and shading typologies. The building identification code integrates geographical and descriptive information, including zone and building typology.

Format: Zone + Building number / Typology

Code: (A1/A)

Description: Zone A, Building 1/ Apartment

Similarly, shading typologies are coded based on architectural period slash orientation followed by geometric configuration.

Format: Period / Orientation + Geometry

Code: (Ne/WV)

Description: New Khmer Architecture/ West, Vertical

This coding system facilitates systematic data organization and enables comparison analysis across zones and architectural periods. Overall, the typology approach provide a structured framework for analyzing the relationship

between shading design, environmental adaptation, and architectural transformation.

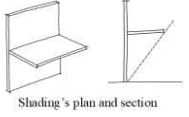
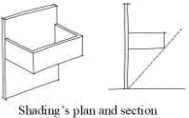
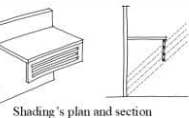
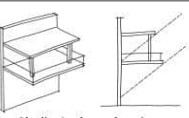
Zone A, Road86						
N	Building Code	Material	Geometry	Orientation	Era	Shading code
1	A1/A	Concrete	Overhang	N	Contemporary	C/NO
2	A2/F	Concrete	Balcony	S	Contemporary	C/SB

Table 1. Parameters data's table use on filed observation with coding system

3. RESULTS AND DISCUSSION

The observation of 240 residential buildings reveals a clear distribution of shading device typologies across the study area. Figure 2 shows balcony shading emerges as the dominant typology, accounting for 49% (118 buildings), followed by horizontal shading and deep verandas, each representing 15% (37 buildings). Egg-crate devices contribute 12% (29 buildings), while hangover shading is relatively limited at 8% (17 buildings). Vertical shading devices are the least observed, comprising only 1% (2 buildings).

The results show that balcony shading is the most dominant typology, indicating its multifunctional role in providing both solar protection and usable living space. Horizontal shading and deep verandas each represent, reflecting moderate use as effective climate-responsive solutions. Egg-crate shading, suggesting a more specialized but less common approach, while hangover shading remains limited. Vertical shading is rarely used, indicating low relevance on the residential in tropical context. Overhangs, horizontal overhangs, deep verandas, and egg-crate devices, are moderately applied, due to practical and functional design. Their implementation is limited by dense urban conditions, where the need for living spaces in urban areas is important. Additionally, lower functional benefits compared to balconies reduce their priority.

Shading Typology	Image	Sample Plan and Section
Type: Hangover (17/240 Buildings or 8%)		 Shading's plan and section
Type: Balcony (118/240 Buildings or 49%)		 Shading's plan and section
Type: Horizontal (37/240 Buildings or 15 %)		 Shading's plan and section
Type: Deep verandas (37/240 Buildings or 15 %)		 Shading's plan and section

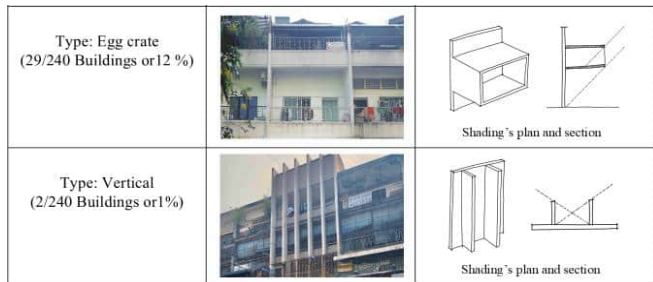


Fig. 2. Typologies of shading devices observed on residential buildings in Daun Penh district

Shading devices are observed across all architectural periods (figure 3), indicating their continued relevance in responding to climatic conditions in residential buildings. The findings reveal that a full range of typical shading typologies is present in both the Contemporary and New Khmer Architecture periods, reflecting a more diverse and adaptive design approach. In contrast, the French Colonial period exhibits a relatively limited presence of original shading devices, largely due to subsequent reconstruction and the integration of newer shading elements over time.

As a result, these shading types are applied selectively, depending on design integration and specific building conditions. Most of shading devices were applied later after the building is built as device for blocking the sunlight. Some buildings were built during the colonial period but had adapted the shading device later, indicating that there are continuous changes in temperature in urban areas. New Khmer architecture period, shading device was the a frequently used strategy to respond to climate change, until contemporary development passive design is less effective and replaced by cooling system because the increasing of global warming.

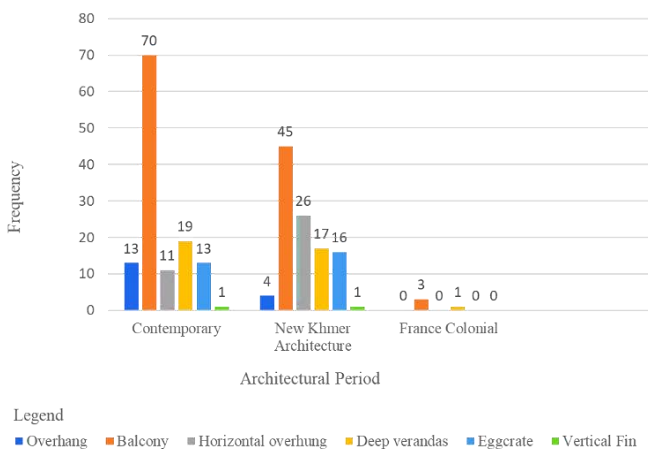


Fig. 3. Shading device topologies across all architectural period

The Chi-square test was conducted to examine the relationship between shading device typology and building orientation based on the observed and expected frequencies by follow the statistic formula [16]. According to table 2, we found the expected values as shown in table 3 by followed formular:

$$E = \frac{(\text{Row Total})(\text{Column Total})}{\text{Grand Total}}$$

Where: E= expected value

Row Total = total of each shading type

Column Total = total of each orientation

Grand Total = total of observation shadings

Shading Typology	North (N)	East (E)	West (W)	South (S)	Total
Overhang	6	2	2	7	17
Balcony	30	42	15	31	118
Horizontal	6	11	13	7	37
Deep-Ver	13	5	11	8	37
Egg Crate	5	8	9	7	29
Vertical	0	0	2	0	2
Total	60	68	52	60	240

Table 2. Distribution of shading devices by orientation (Table of Observed Values)

Shading Typology	North (N)	East (E)	West (W)	South (S)
Overhang	4.25	4.81	3.68	4.25
Balcony	29.5	33.43	25.56	29.5
Horizontal	9.25	10.48	8.01	9.25
Deep-Ver	9.25	10.48	8.01	9.25
Egg Crate	7.25	8.21	6.28	7.25
Vertical	0.5	0.56	0.43	0.5

Table 3. Distribution of shading devices by orientation (Table of Expected Values)

The Chi-square test calculated by the followed formular: $X^2 = \frac{(O-E)^2}{E}$

Where: O= observed value

E= expected values

The degree of freedom calculated by the followed formular: $df = (r - 1)(c - 1)$

Where: r = number of rows

c = number of columns

The probability value (P-value)

formula: $P = P(X^2, df)$

Where: X^2 = Chi-square value

df = degree of freedom

Since $P < 0.05$, the result is statistically significant. This means there is a relationship between shading type and orientation.

According to table 2 and 3, the analysis produced a Chi-square value (X^2) of 31.24 with 15 degrees of freedom (df), resulting in a P-value of approximately 0.008. Since the P-value is lower than the significance level of 0.05, the null hypothesis of independence is rejected. This indicates that there is a statistically significant association between shading device types and façade orientation.

Shading Typology	Orientation response	Zone	Functional/ Response
Overhang	Moderate (N, S) Weak (E, W)	Limited used in zone A and C	Basic sunlight protection from Hight angle (direct sun blocking)
Balcony	Strong (E) Moderate (W, S, N)	All period in all zones	Solar control and social, family space (hybrid function)
Horizontal	Moderate (N, E, W, S)	More used in zone B	Response to high sunlight angle control
Deep-Ver	Moderate (N, W, S) Weak (E)	All period, more visible in zone C	Solar control and social, family space (hybrid function)
Egg Crate	Moderate (E, W, S) Weak (N)	Increase in contemporary	Response to sun multi directional control (horizontal and vertical shading)
Vertical	Weak (N, E, W, S)	Rare across all zone (all period)	Potential low angle sunlight control (rarely use on residential building)

Table 4. Relationship matrix between shading device typologies and parameters

Relationship between shading typology and parameters (Table 4), highlighting the functional and climate response of shading in residential design. Orientation

response depends on the typology; balcony shading is very flexible, especially east-oriented façades, which are well suited to avoid the morning sun. Overhang and veranda shading systems respond to south and north orientations which is a basic sunlight protection from high angle, egg-crate systems are suitable for multi-directional orientations, horizontal louvers are moderately used to protect the high angle sunlight from all orientation, vertical fin is rarely use on residential building due to its only responded to low angle sunlight control and mostly is for façade design aesthetic. Concrete is the main shading material used in the urban housing of Phnom Penh, which stresses its durability. Other shading materials such as tile and zinc are scarcely employed, featuring only on deep verandahs and horizontal louver.

In summary, the matrix shows that solar shading typologies are not individual elements; rather, they are a comprehensive response to the architectural needs of their climatic, material, evolutionary, and social function.

4. CONCLUSIONS

This study highlights the use and function of shading systems in improving the thermal performance and environmental responsiveness of residential buildings in the Daun Penh district of Phnom Penh, Cambodia, we need a simulation to proof in the next finding. This study shows the significant relationship between shading device typology and façade orientation. The results indicated a statistically significant association between the two variables ($\chi^2 = 31.24$, $df = 15$, $p = 0.008$), suggesting that the distribution of shading device types varies across different building orientations. However, several expected cell frequencies were below the recommended threshold, with some values less than 1, thereby violating the assumptions of the Chi-square test.

The design of shading devices is moderately influenced by building orientation, with balcony shading identified as the most prevalent typology due to its combined environmental and functional benefits. This form is particularly common on eastern and southern façades, while horizontal shading devices are more frequently applied on western façades to mitigate intense afternoon solar radiation.

Although concrete is the dominant material used across all buildings, the geometric configuration of shading devices emerges as the key factor linking orientation, materiality, and architectural style. Over time, shading design has evolved from relatively simple passive features in the colonial period to more integrated and climate-responsive strategies during the New Khmer Architecture period, and to increasingly diverse and in contemporary development.

Overall, the effective shading design results from the integration of climatic considerations, architectural evolution, and façade composition. The limitation of this study provides

the significance of further work to find out the effectiveness of shading devices in other factor such as thermal performance of indoor environments when applying these various shading typologies and the perspective of architects on their experience of using shading on their designs.

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