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Generate Passive Breathable Urban Facades for Interior Thermal Comfort in Tropical Climate Guided by Traditional Facades

I. Tasnova[1], H. Imamur[2], N. Meherun[3]

[1]Department of Architecture, Sonargaon University, Dhaka, Bangladesh (tasnova088@gmail.com)
[2]Department of Architecture, Sonargaon University, Dhaka, Bangladesh (imamur.hossain@gmail.com)

Abstract

The study focused on exploring opportunities to derive breathable facades in tropical climates guided by its traditional facades. Currently structures are enveloped by climate insensitive modern urban facades. Often, the setback regulation is seen to be violated leaving no space for ventilation and minimizing necessary green area. Consequently, occupants are inclined to use mechanical ventilation to neutralize aggressive interior thermal conditions. On the other hand, traditional facades provided thermal comfort. The Research adopted a qualitative research method. Attributes of both traditional facades and modern facades that are responsible for affecting interior thermal comfort were identified through literature review and evaluated through SWOT analysis. The case study areas were chosen to compare interior thermal comforts provided by both traditional facades and modern facades located in the same tropical climate. Key findings evaluated that the structures with traditional facades, even being situated in same context with the modern structures with hot interiors, provide relatively more interior thermal comfort. The attributes of traditional facades can be reinvented to fit into modern facades for interior thermal comfort. Finally, the research proposed several strategies aimed at generating a passive breathable urban façade for interior thermal comfort in tropical climates.

Keywords: *Traditional Facades, Breathable Urban Facades*

1 Introduction

Traditional facades all over the globe have repeatedly provided interior thermal comfort due to their contextual design which employs architectural features, shading devices, materials, and colors strategically to secure itself from climatic elements. Modern facades contradict these strategies and are usually unwilling to adapt strategies employed by the traditional facades. Consequently, the thermal comfort in the modern building interior is suffering due to uncontextual and rather McDonalized facades. Reinventing the modern urban facades will be an effective way to make use of strategies employed by traditional facades to achieve interior thermal comfort. The key research questions of this study are; what are the attributes of modern facades in urban context that are catering to interior thermal dissatisfaction in tropical climates; how to create passive breathable urban facades that establishes interior thermal comfort in tropical climates. The research aims to explore factors to generate passive breathable urban facades to establish thermal comfort in interior spaces in tropical climates. To achieve the research aim, two objectives have been formulated based on the research questions. The two objectives of this research are to identify the attributes of traditional facades that establish interior thermal comfort in tropical climates and to generate passive breathable urban facades that will establish interior thermal comfort in tropical climates.

1.1 Research Problem

The modern structures, in many cities with tropical climate, around the world are expanding vertically as highrise and midrise due to economic growth, land unavailability and high land prices. These structures usually are made of climate insensitive materials, colors, shading devices and architectural features, which are mass produced for ease of availability and faster building construction. The facades of these structures are also heavily influenced by western architecture and hence are not sensitive to the tropical climate. Such McDonalized approach has not only cost cities within tropical climate their architectural identity but also brought about thermal dissatisfaction in the interior spaces. Occupants of both nonresidential and residential structures with modern facades in tropical climates are inclined to use mechanical ventilation due to interior thermal dissatisfaction. Consequently, such mechanical ventilation systems further heat the surrounding by discharging hot air and it increases energy consumption. Moreover, many modern urban facades are breathable but require the purchase of electricity. On the other hand, traditional architecture maintains thermal comfort in the interior spaces with minimal damage to the surroundings due to strategic passive façade interventions.

2 Thermal Comfort and Breathable Facades

A.P.Gagge defined thermal comfort as the condition of mind which expresses satisfaction with the thermal environment and it is an accepted definition by ASHRAE in 1986. International standards, ASHRAE-55 and ISO 7730 have been established for specifying combinations of thermal environmental factors for indoors to achieve acceptable thermal conditions for inhabitants. According to these two international standards an occupant's thermal comfort can be predicted by six parameters in PMV equation by P.O.Fanger accepted by ASHRAE; air temperature, radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation (lotfabadi and Hançer, 2019). P.O.Fanger developed two equations which are Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). PMV estimates how many people will feel dissatisfied in a space by its thermal conditions based on measurements of the six parameters accepted by ASHRAE, discussed earlier in this section. On the other hand, PPD is equated by user's perception of heat in a room. According to research conducted recently (Surjamanto_Wonorahardjo et al., 2022) and (Suradhuhita et al., 2021), different façade systems significantly affect indoor thermal comfort. Hence façade in this research is considered to be one of the attributes that affect thermal comfort.

2.1 Facades

In this research façade is all external elevations of a structures. Façade can be both active and passive. Passive design strategies on the facades use ambient energy from the environment such as seen in traditional structures and active design strategies on the facades use externally purchased energy to make it function such as operable louvers and façade lighting.

2.1.1 Operational Variables of Facades

In this research we are concerned with two types of façades, traditional facades and modern urban facades. The operational variables of these two types of façades, derived from extensive literature review in this research, are material, color, shading devices, and architectural features.

2.2 Traditional Facades

In this research the traditional structures considered are in contexts with tropical climate. The indicators of all four operational variables of traditional facades are studied in countries with tropical climate; refer to Table 1 and Figure 1. It is studied that traditional facades employed materials such as wood, mud, stone, brick, lime plaster, the color applied was light color in most cases, shading devices such as shutter, extended roof, arcaded buffer spaces, depressed window within thick walls were incorporated and architectural features such as window, openings in courtyard, lattice screen, terrace, balcony, verandah, courtyard, buffer spaces, inclined roof extensions, cavity walls, tall rooms were used. These features or indicators established interior thermal comfort.

2.3 Modern Urban Facades

At present most urban structures have modern facades made of mass-produced materials, are acquired from different contexts, are climate insensitive, and have McDonalized architectural features. Such modern urban facades in tropical climates often fail to deliver interior thermal comfor. The indicators of all four operational variables of modern urban facades are studied in countries with tropical climate; refer to Table 1. It is studied that modern urban facades employ materials such as bricks, concrete, glass, steel, use variety of colors, incorporate inadequate or energy consuming shading devices and use architectural features such as balconies with small depth from external wall, flat roof, wall, large windows. In a study by Kamal, 2020 a variety of materials used in modern urban facades were mentioned which included self-cleaning glass, electro-chromatic glass, thermo-chromic glass, fritted Glass, LED facades, composite metal, rain-screen cladding, nano materials and solar nano technology, building integrated photovoltaics (BIPV), phase change materials, ethylene tetrafluoro ethylene (ETFE), polycarbonate panels, vacuum insulated panels, aerogel, suspended particle devices, stainless steel panels, FRP composites, aluminum panels and terracotta. But these materials have drawbacks such as low durability, costly and complicated installation, use of chemical, high electricity consumption, detrimental effect to human health, environment pollution, high sound transmission, low heat resistant, expansive maintenance, non-fireresistance, and quality fluctuations. Hence modern urban facades made with such materials cannot be labeled as passive facades in most cases and are therefore not considered in this research.

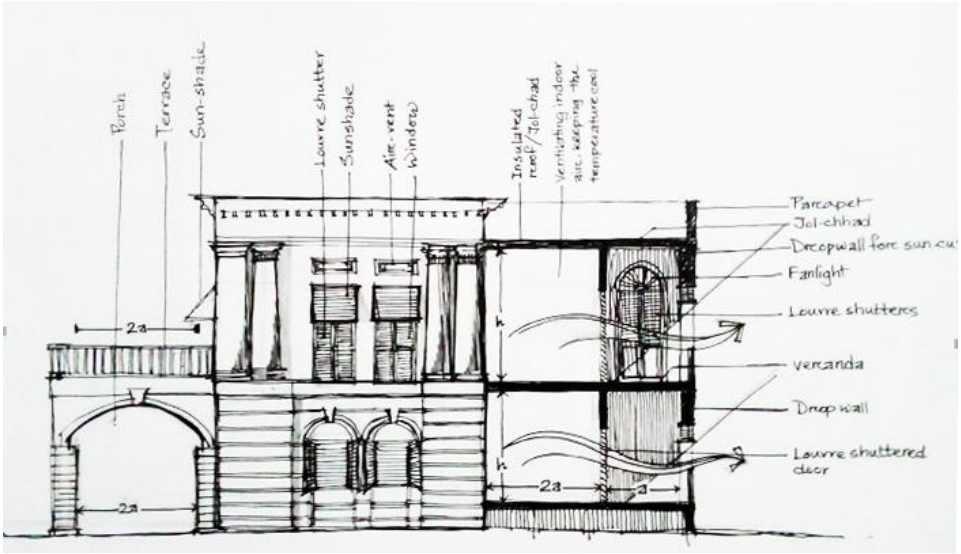

Figure 1. Indicators of Traditional facades.
(Adapted from Prianto and Depecker, 2003; Samuel et al., 2017; Larsen, 2015; Wonorahardjo, 2022; Azmi, 2022; Andoni et al., 2018; Shaeri et al., 2018; Stasinopoulos, 2023; Bassily et al., 2022; lotfabadi and Hançer, 2019; Dili et al., 2010; Rahman and Wibowo, 2021; oocities, 2009; and Karunathilake et al. 2018; and Kamalaseelan, 2021; by Authors-Iqbal et al., 2023).

2.4 Passive Breathable Urban Facades

From the 1980s to 1990s, facade technologies emerged to eliminate condensation and improve thermal comfort and solar control for improved performance of sealed glazing. It developed into modern double-skin configurations with vapor permeable filters. The air space widths range from 40 to 500 mm. The wider gaps can accommodate architectural features such as operable louver blinds inside the cavity space (CSTB, 2007, Keinlin 1994, Bonham, 2019). At present, use of such breathable facade technology is mostly limited to France where each application is reviewed by a state agency on behalf of the French government to aid the emergence, development, and safe use of innovative building technologies during design stage. Breathable façades are evaluated by each application's climatic conditions, materials, and dimensional configuration for further recommendations (Bonham, 2019). The courthouse in subtropical climate of Grenoble, France; designed by Claude Vasconi employs both ventilated and unventilated double-skin breathable facades in its envelop and has climate adaptive features for thermal performance, solar control, and easy maintenance (Bonham, 2019). Passive breathable urban facades can have varied features depending on context and can be an amalgamation of traditional façade indicators and modern urban façade indicators; refer to Figure 2.

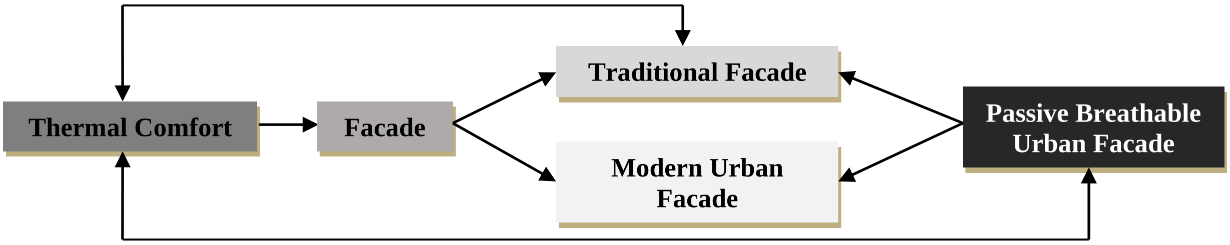

Figure 2. Interrelationship between thermal comfort and types of façades.
(Adapted from Surjamanto_Wonorahardjo et al., 2022 and Suradhuhita et al., 2021 by Authors-Iqbal et al. 2023)

3 Research Methodology

Considering the research questions, aim and objectives, the qualitative method approach was adopted. Qualitative research is an emergent process rather than tightly prefigured (Creswell J W and Creswell J D, 2017). Yin (2013) describes the case study method as an empirical inquiry that investigates a contemporary phenomenon within real-life context when the boundaries between phenomenon and context are not clear; it uses multiple sources of evidence (Yin, 2017). In this research traditional facades and modern urban facades were studied from three countries with tropical climate to collect secondary qualitative data. The case studies are researched to derive in depth data collection. This research included one research technique for data collection, which is literature review of secondary data from foreign case studies. The data availed was used for data analysis comprising of comparative content analysis and SWOT analysis. Findings from the data analysis were later used to establish the recommendations to generate passive breathable urban facades in tropical climates.

4 Findings and Analysis

This section presents the analysis and recommendations based on the research questions, aim and objectives. The comparative qualitative data analysis of both modern urban facades and traditional facades filtered common indicators from the three case study areas that are catering to interior thermal dissatisfaction and interior thermal comfort respectively; refer to Table 1. A SWOT analysis of all the common indicators of traditional façade is done to find the most effective indicators responsible for thermal comfort.

4.1 Assessment of Study Area

The case study areas were chosen from Jaffna in Sri Lanka, Kerala in India, and Pematang Purba in Indonesia; refer to Table 1. These sites have both urban and traditional façades in the same urban context, with tropical climate. Both modern urban façade and traditional façade studied are passive facades situated in tropical climates to generate passive breathable urban façade for tropical climates which will ensure interior thermal comfort. Hybrid and active facades were not included in the research. Sri Lanka traditional façade provide more indoor thermal comfort than modern structures (Kamalaseelan, 2021). Kerala traditional facades are very effective in establishing interior thermal comfort unlike modern facades (Naseer et al., 2010 and Akella, 2005). Kerala traditional façades are passive and maintain interior thermal comfort regardless of outdoor climate changes (Dili et al., 2010). Simalungun traditional facades in Pematang Purba successfully establish interior thermal comfort (Rahman and Wibowo, 2021).

5 Conclusion and Recommendation

As mentioned in section 2.4 passive breathable facades can be an amalgamation of traditional façade indicators and modern urban façade indicators depending on context; refer to Figure 3.

5.1 Recommendations to Generate Passive Breathable Urban Facades

Passive breathable urban facades, to achieve interior thermal comfort in tropical climates, can be generated from the findings of SWOT analysis on four operational variables of façade, refer to Figure 3. The material should have low thermal mass, high diffusion coefficient and be light weight for cool interior space. Examples of such materials are mud, mud concrete blocks, clay tiles, wood, etc. The color should be a light color as it absorbs less heat. Shading devices such as louvers, fins, shutters, window shades, arcades, and extended roofs must be adequate and sufficiently designed. Windows can be depressed within thick walls which will act as shading. Architectural features should be climate sensitive. Windows installed should be in a north-south orientation. Window to wall ratio if around 20% thermal comfort is optimized (Karunathilake et al., 2018). Double glazing is preferable to efficiently reduce heat gain. The glass should have lower solar heat gain coefficient (SHGC) to lower heat transmission. Cavity walls provide better thermal insultation hence reduces heat transmission significantly. Balcony, terrace, verandah, courtyards, openings in courtyard aid to maintain interior thermal comfort. The depth of balcony, terrace, verandah, or arcaded passages, from exterior façade aid to create buffer space between interior rooms and exterior surrounding required for thermal comfort. Tall rooms cause a stack effect which makes the interior cool. Extended roofs with conical shaped clay tiles reduce internal heat loads. It is also observed from literature reviews that lattice or jali features keep the interior cool. Passive breathable facades can also be generated based on an integrated building information modeling (BIM), to derive parametric building energy simulation from parametric software framework, during design phase to calculate desired thermal comfort. It will aid to know the exact depth of buffer spaces, room height, area of windows, wall thickness, wall cavity space, orientation and location of openings, configuration of shading devices and properties of materials required to achieve thermal comfort.

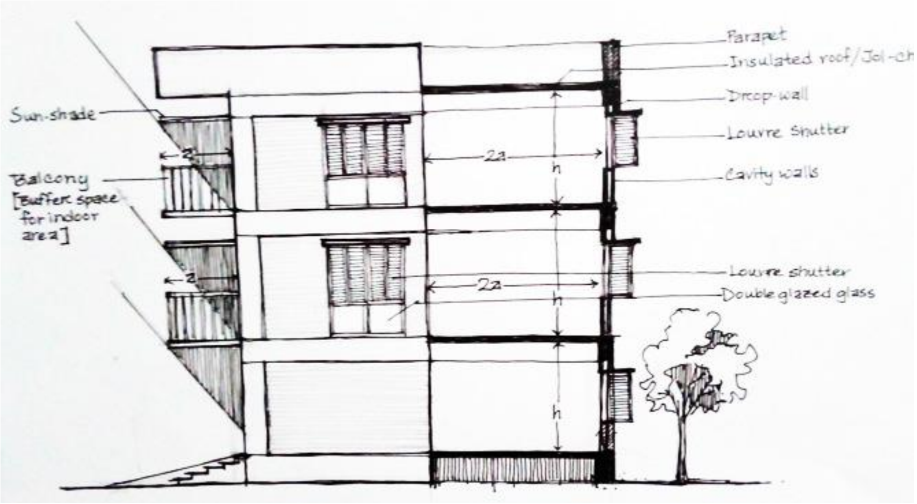

Figure 3. Passive breathable urban façade for tropical climate by Authors-Iqbal et al., 2023

Table 1. Comparative qualitative data analysis of both modern urban facades and traditional facades that are catering to interior thermal dissatisfaction and interior thermal comfort respectively in the case study areas. (Adapted from Prianto and Depecker, 2003; Samuel et al., 2017; Larsen, 2015; Wonorahardjo, 2022; Azmi, 2022; Andoni et al., 2018; Shaeri et al., 2018; Stasinopoulos, 2023; Bassily et al., 2022; lotfabadi and Hançer, 2019; Dili et al., 2010; Rahman and Wibowo, 2021; oocities, 2009; Karunathilake et al. 2018; Kamalaseelan, 2021; Ananacha, 2014; Adrienn Gelesz et al., 2020; Hosseini et al., 2020; Naseer et al., 2010; and Akella, 2005; by Authors-Iqbal et al., 2023).

Attribute that affects all parameters of thermal comfort	**Types of façades in this research**	**Operational Variables of Facade**	**Passive Indicators of facades for interior thermal comfort**			
				Jaffna, Sri Lanka	**Kerala, India**	**Pematang Purba, Indonesia**
Facade	Traditional facade	Material	Mud (thermal mass)	✓	✓	x
			Wood (humidity buffer)	✓	✓	✓
			Stone (faster heat loss)	x	✓	x
			Brick (higher diffusion coefficient)	✓	x	x
			Lime mortar	✓	✓	x
		Color	Light colors	✓	✓	✓
		Shading Devices	Shutters (placed outside)	✓	✓	x
			Arcades	✓	x	x
			Extended Roof	✓	✓	✓
			Window depressed within thick wall for shade	x	x	x
			Shade over Window	x	✓	x
		Architectural Features	Window (size, location, north-south orientation, double glazing, lower solar heat gain coefficient (SHGC) of the glass)	✓	✓	✓
			Openings in courtyards	✓	x	x
			Lattice screen	x	x	x

			Balcony (Configuration)	✓	x	x
			Terrace	x	x	x
			Verandah	✓	✓	x
			Courtyard (Open to sky)	✓	✓	x
			Buffer spaces (arcaded passage surround internal rooms)	✓	x	x
			Inclined Roof extension (with conical tiles/ clay tiles)	✓	✓	✓
			Cavity walls	Not Studied	Not Studied	Not Studied
			Tall rooms	Not Studied	Not Studied	Not Studied
	Modern urban façade	Material	Brick	✓	✓	✓
			Concrete	x	x	x
			Glass	x	x	x
			Steel	x	x	x
		Color	Varied	✓	✓	✓
		Shading Devices	Inadequate or absent	✓	✓	✓
		Architectural Features	Wall	✓	✓	✓
			Flat Roof	✓	✓	✓
			Balcony with less depth	✓	✓	✓
			Large windows	✓	✓	✓

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