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Enhancing Thermal Confort in Terrace Houses in the Tropics

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***Abstract*— The paper investigates through systematic review on how thermal condition of terrace houses could be naturally enhanced for suitability in tropical regions. Internal courtyard was identified as one of the best way of achieving that. Other factors such as, human activities, building materials and courtyard configuration/orientation were not considered in this review. But emphasis were only on the internal courtyard as an element. Also ways to identify and ensure more effectiveness of the courtyard, such as, windows opening into it, introducing vegetation and use of water ponds or pools within it.**

Keywords—Terrace; housing; Tropics; Thermal

I. INTRODUCTION

Terrace housing describes a group of houses built in a row, adjoining one another and having shared side walls. Originating in 17th century Europe, terrace housing was conventionally of medium density accommodation. Today, however, terrace housing has been adapted to various socio-economic levels of occupants. One of its most critical characteristics, is its spatially deep planning. In tropical regions where they are constructed, regular high temperatures create thermal discomfort levels for occupants of the houses. Typical examples are Nigeria and Malaysia where terrace housing is quite extensive, and the occupants largely depend on artificial ventilation for comfort.

It is in this context that this paper undertakes a systematic review to find out ways of enhancing the thermal condition of the terrace housing, in order to be more sustainable in terms of energy conservation and quality of interior air

II. CHARACTERISTICS OF TERRACE HOUSING

Terrace houses can be defined as either 'terraced' or 'semi-detached (Aucland Council, 2017). When 'terraced' it means that three or more houses are constructed joined to one another in a row, sharing side walls, hence, they are also called row housing (Quansah, 2016). On the other hand, when there are only two houses in a row, sharing one side wall, it is known as semi-detached.

Emerging in the 18th century Europe, according to Professor Richard Rodger ("All together now - the return of terraced housing," 2000), immediately after the Great Fire (Paterson, 2011), terrace housing has become conventionally for accommodating middle income urban families (Mohit & Abdul Rahim, 2012). Some classical characteristics (Quansah, 2016) have been attributed to it among which are, built in rows, patterned bricks, Terraces (literally), bay and sash windows, Stained glass, Fireplaces in every room, and Porches. Today, however, around the world including Europe itself, terrace housing has been adapted to various socio-economic levels of occupants, with additional characteristics like, car parking within the house (integral garage), in-curtilage (within shared access) or on street. They are also typically in single or double storeys, planned in gridiron layout to maximize land use. However, one critical characteristic which has remained since then, is the spatially deep planning of terrace houses (Lim & Lim, 2014), where Tahir et al. (2010) submitted a typical dimensions of 5.4m (18 feet) to 7.2m (24 feet) width, and a depth of 18m (60 feet) to 24m (80 feet). This disproportional dimensions were closely corroborated by Abdul-Razak, Leardini, & Nair (2015)

Typical Terrace Housing in Nigeria

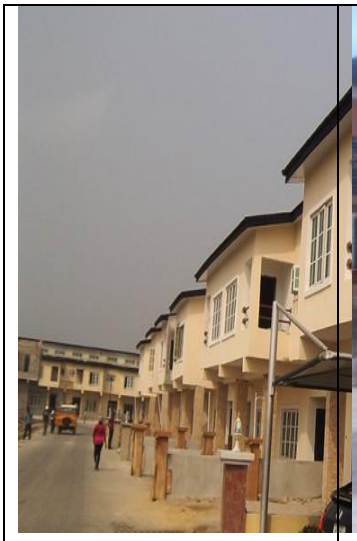

Figure 1 Newly Built Shell 4 Bedroom Terraces Source: http://mercy-homes.com/property/newly-built-shell-4-bedroom-terraces-lekki-gardens/

Figure 2 Oba Elegushi Royal Estate (lekki-right), Ikate Elegushi, Lekki, Lagos Source: https://www.nigeriapropertycentre.com/for-rent/flats-apartments/self-contained/lagos/lekki/ikate-elegushi/showtype

Figure 3 erraces, Bandar Bukit Puchong Freehold Fully Furnished 5R/4B Source: https://www.propsocial.my/property/1015/bandar-bukit-puchong/nilam-terraces

Figure 4 Eco Summer, Eco World (Setia Indah) Eco Summer, Johor Bahru, Johor, 4 Bedrooms, 1875 Sqft, Terraces / Link-Houses for Source: http://www.propertyguru.com.my/property-listing/eco-summer-eco-world-setia-indah-for-sale-by-allan-su-25017107

III. Thermal Conditions in Tropical Terrace Housing

Natural ventilation has recently acquired renewed interest from researchers. It is a reawakening related to the general concept of sustainability, and specifically to energy conservation, interior air quality, and quality of life. In tropical countries, both humid and dry, natural ventilation is of paramount importance owing to the fact that, the climatic conditions are mainly characterized by high temperatures, and mostly low wind velocity. Of course in humid tropics, the humidity causes additional problems. Classically defined, tropical regions have temperatures higher than 18^{o}C, although (Trewin, 2014) cited the narrowness of this definition by citing exceptions like high altitude areas where temperature decreases at 6oC per 1000 meters. These characteristics are relatively constant because unlike in the temperate regions, variations in tropical climatic conditions are considerably less (Khaliq et al., 2015; Jaszewski et al., 2011).

These conditions constitute the major factors leading to very low thermal comfort levels for occupants of houses. Terrace housing is one housing typology among the most affected by this thermal discomfort (Chung, Ahmad, Ossen, & Hamid, 2015), owing to the earlier stated reason of having spatially deep floor plans. Malaysia presents a very suitable case to explore the terrace housing phenomena. One reason is its tropical location, and another reason is that, terrace housing has become the most common and in many cases, the cheapest housing type in Malaysia, hence it has become the predominant accommodation (Sazally, Omar, Hamdan, & Bajunid, 2016) for the country's masses (Tahir et al., 2010). In fact, Azzmi & Jamaludin (2014) posited that it is the most widespread mode of urban mass housing in urban areas.

Unlike the traditional Malay building which employs practical natural means of ventilation, the terrace houses have had to depend heavily on artificial means for achieving adequate ventilation. It is so bad that, according to Al-Yacouby, Khamidi, Nuruddin, Farhan, & Razali (2011), approximately 75% of the Malaysians depend on artificial air conditioning for interior comfort. Nigeria, similar to Malaysia, is also a tropical country, although it is in the tropical wet & dry region. Nonetheless, high temperatures are frequently experienced, especially in Northern Nigeria, where average day measures can reach as high as 38^{o}C (Usman, Yelwa, Gulumbe, & Danbaba, 2013; Omonijo, Oguntoke, Matzarakis, & Adeofun, 2011).

The tide seems to be against classical terrace housing in many aspects. For instance, (Bello, Dola, & Shaba, 2014) submitted that, green landscape area, terrace housing layout is inappropriate for occupants' needs. The inappropriateness was reflected by the rapid and extensive modifications it underwent in the hands of its occupants, to the extent that Sazally et al. (2016) confidently questioned its sustainability and

adoptability to the cultural and climatic needs of the occupants. That was the reason Hutchinson (2002) advocated for a house design which reflects the regions climate, materials, and cultural background.

Figures 1 and 2 show typical terrace houses to get the picture of the thermal problem in this typology. It should however, be born in mind that its origin was in Europe, a temperate region where conservation of heat was desirable. Looking at Figure 1, left floor plan, which is the ground level, it is quite narrow and deep with the various spaces arranged linearly. As a result of that, external windows were only possible on the narrow end walls. In Figure 1, if any natural ventilation would be required, then windows and doors of RR-1, RR-2 and RR-3 must be left open. The same factor applies to the upper floor level, where DD-1, 2, 3, and 5 have one side external windows. For Figure 2 also, in the case of the middle house or intermediate unit, the condition is the same. PP-1 to 4 would not be ventilated and the heat trapped would make the rooms uncomfortable.

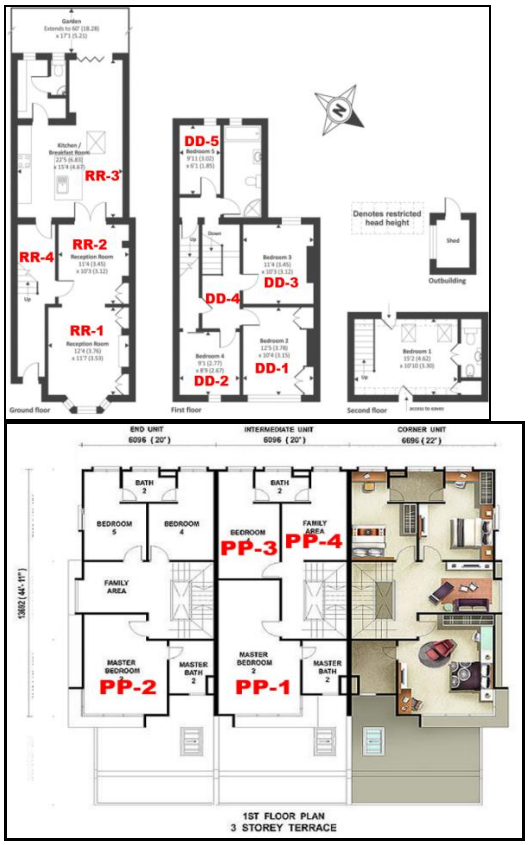

Figure 1 & 2: Typical terrace houses

Note: Adopted from Terraced House Plans, ("Terraced House Plans," 2016)

These unacceptable housing conditions are indeed the result of what (Tahir et al., 2010) called, spatial inflexibility, design insensitivity and ultimately, mundane design.

IV. Thermal Enhancement of Terrace Houses

All the earlier discussion have established one fact, that terrace houses have not been typically designed for suitability to the tropical climate generally. Achieving natural ventilation in terrace houses is important in terms of sustainable energy consumption. Researches have been conducted into ways of modifying the typical terrace house typology to better suit the tropical region. Sadafi, Salleh, Haw, & Jaafar (2008) investigated the impact of incorporating courtyard within the terrace house through simulation. The study showed that, as long as spaces inside the house have openings only into the courtyard, there will be increased heat gain in those spaces. However, spaces with openings both to the outdoors and into the internal courtyard, recorded better thermal conditions - shown in Figure 3.

Figure 3: Internal courtyard in a terrace house

Note: Adopted from *Skylight House by Chenchow Little Architects* ("Skylight House by Chenchow Little Architects," 2013)

Such design can reduce the air temperature of the courtyard by 2–3o (Berkovic, Yezioro, & Bitan, 2012). It is important to note that using internal courtyard to enhance thermal comfort within terrace houses is irrespective of, and with due respect to the fact that, the courtyard's configuration and orientation determines the level of its impact (Almhafdy, Ibrahim, Ahmad, & Yahya, 2013). This study rests on the premise that other methods can be incorporated, whatever the configuration and orientation of the internal courtyard. For example, earlier, Al-Hemiddi & Al-Saud (2001) proved that, if an internal courtyard is covered during daytime and opened during the night, its temperature will drop significantly. Also, experiments by Chatzidimitriou & Yannas (2004) testified to the positive effect of adding trees, shrubs or even grass, in the internal courtyard, as a means of enhancing its thermal comfort. In fact, during cold weather, they provide a warming effect. Furthermore, water pools have cooling effects on their surroundings through evaporative cooling which increases the humidity (Gupta & Tiwari, 2016), i.e. in the case of dry hot tropical regions like Northern Nigeria.

V.CONCLUSION

The paper set out to explore, through systematic review, how the thermal condition of terrace houses can be naturally enhanced for suitability in tropical regions. It identified internal courtyard as the best way of achieving that. Furthermore, it identified ways to ensure more effectiveness of the courtyard, such as, windows opening into it, introducing vegetation and use of water ponds or pools within it. However the paper did not consider factors such as, human activities, building materials, and courtyard configuration/orientation, but focused only on the internal courtyard as an element.

VI.LIMITATION

This study only consider Malaysian and Nigerian tropical climate for further studies and general conclusion other tropical climate should be consider.

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