



RESILIENT LIVING BY OPTIMIZING THE BUILDING FAÇADE IN DESIGNING POST-COVID HOUSING

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Abstract

The living performance in sustainable development outline contributing factors towards efficiency, such as ecological, economic, health, and social integration. The performance of facade design must be emphasised to describe resilient living and access to mitigate the design of post-coronavirus disease (COVID-19) housing. The spread of the pandemic underlines the importance of providing quality of life and well-being in the building environment, hence highlighting a crucial need to improve indoor air quality and passive building performance to minimise the transmission of COVID-19 and indoor airborne diseases as a result of poor ventilation. The passive building performance and facade complement the energy demand and reduce heat gain. Currently, passive design and health are emphasised to link the environmental design approach and architecture and highlight the quality-of-life post-pandemic. The study aims to provide important healthy indoor strategies and passive building performance for open-plan home-office design, to investigate the open-plan home design with optimum thermal performance based on the passive indoor environment, and to examine the bioclimatic response and energy efficiency of home-office design during the pandemic. The responsiveness of bioclimatic and modular construction incorporated with the new home-office design aim to save energy through sustainable material. The Integrated Environmental Solutions Virtual Environment (IESVE) computer software was utilised using simulations involving ranges of illuminance levels in daylight and revealed the acceptable levels of between 300 lux to 500 lux for the home office area. The results demonstrated that the optimum range of solar heat gain coefficient (SHGC) of 0.46 and a U-value of 0.04 W/m² K reduced the indoor temperature by 5 degrees Celsius during peak time and maintained the air-condition at 28 degrees Celsius, which was within thermal comfort level.

Keywords: Passive indoor performance, Daylighting, open-plan home

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INTRODUCTION

The emergence of COVID-19 has changed life trends, tactics, and well-being, particularly in neighbourhoods. The growing role of a home has tremendously reshaped behavioural trends. Therefore, the solutions for immediate change focus on environmental, social, and physical aspects. The passive design strategies are essential to encourage health and safe living relevant to the current pandemic in housing development. The light harvesting for facade design could maintain the quality of daylight penetration from the fenestration system (Vlachokostas et al., 2017). Moreover, the daylighting arrangement in the interior could satisfy the occupants. Most efforts in facade integration in buildings only highlight the colour change (Costa et al., 2019), while the explored technologies regarding the building envelope, facade components, and the efficient use of green resources must be integrated into the building design and construction. Thus, several strategies have demonstrated the benefits of construction technology.

Considering that the virus could be spread and transmitted through modified heating, air, and surfaces through human contact, the strategies in providing indoor air quality could mitigate the disease spread (Navaratnam et al., 2022). Furthermore, Lim et al. (2021) stated that work from home changes the lifestyle that avoids confined and enclosed spaces and promotes social distancing of one to two metres to prevent close human contact. The building facade for the home-office acts as a limit and filter through supplementary measures for glare protection. The study emphasised technology resiliency that contributes to the preparedness phase during any outbreak based on the density of people in a space or room. Currently, the acceptable indoor lighting level for learning spaces follows the standards and guidelines of between 300 lux to 500 lux (Husini et al., 2021). Nonetheless, few studies outline the types of a facade system that influence indoor lighting. Hence, the study constructed the design strategies that emphasise resilient living in housing settlements. Issues on building design contamination without proper daylight and fresh air cause severe environmental pollution (Peter et al., 2020).

Lim et al. (2021) stated that factors such as connectivity, crowding, and order directly spread the virus provided that people maintain a safe social distance. Instead of sufficient opening for daylighting and ventilation, the building walling material should ensure thermal performance for humans. In the pandemic response phase, the implementation of sustainable material and resilient designs should be integrated to better manage the maintenance of resilient living and to enhance understanding of health and architecture. The study mainly focused on how the passive design of wall facade and internal layout could impact the home-office space setting towards a healthy environment. The development of the building facade with the effort to reduce the electricity demand of the air-conditioning system should outline the thermal transfer value (OTTV) regulation (Chan et al., 2014). The study calculation demonstrated more

possibilities on thermal behaviour when the facade area was installed with materials that reflect the heat gain.

The study aims to investigate the open-plan home design with optimum thermal performance based on the passive indoor environment. Secondly, the study aims to examine the bioclimatic response and energy efficiency of home-office design during the pandemic. The facade design for occupant wellness could be achieved by controlling the indoor temperature, incorporating sunshade, and optimising the window to wall ratio. The effectiveness of fenestration could balance the building management and increase occupant wellness. The source of psychological comfort is stimulated via lighting, colours, materials, sizes, and shapes while balancing the internal-external relationship in housing (Bettaieb & Alawad, 2018). Functional flexibility is needed to accommodate numerous activities in a home, but the space arrangement should configure the interconnection between the indoor-outdoor environment (Bettaieb & Alsabban, 2020). Presently, working from home is a norm and the number of hours residents spend is increasing, which complicate the redesign and retrofit of the indoor area concerning daylight and fresh air (Peter et al., 2020).

Internal planning in dwelling

In the preparedness phase, indoor planning and house material measures should utilize a technological approach for better resilient living. The decision towards developing proactive measures of the socio-cultural and physical environment is highlighted through post-pandemic sustainability living (Bettaieb & Alsabban, 2020). The preparedness phase planning in housing is reflected in the healthy environment concept where the focus is on the internal layout and reduction of temperature to promote human thermal comfort in living. Tang et al. (2021) proposed that the surveillance system using digital information was partly the plan during the outbreak. Natural daylight concerns the stimuli to energy consumption. The design variables to measure an efficient classroom must experiment with the visual comfort metric together with the efficient layout. Meanwhile, the responsive facade covers the design aspect of light intensity (Ahmed et al., 2016). Previously, the efficient facade material was measured by adjusting the position of light intensity.

For student performance, the minimum glazing factor of 2% was achieved with 75% occupied areas in a space (Arabi et al., 2018). The acceptable illuminance level in classrooms was achieved when the ranges were measured when the occupant density reached 25 to 50% and the window to wall ratio was 70% (Husini et al., 2018). The light interaction with surfaces or facades predicts daylight performance, while the optimization of daylight performance with various materials captures the visual comfort from the dynamic modular grid. Presently, the planning of internal spaces applies the open-space concept (Manaf et al., 2019). Although the approach produces conflicting designs with privacy

and traditional layout, eliminating barriers with walls and clear divisions are necessary during the lockdown and suitable in building the home office environment.

The housing characteristics of the internal layout enable cross ventilation and lighting. The pandemic changes the home design and transforms into a fully functioning home office. The homeworking space promotes the working environment associated with productivity through the performance measures of windows and walls for facade layering. The sustainability and energy efficiency in dwellings could achieve human comfort by highlighting the waste materials as insulation to reduce heat and better indoor quality to prevent airborne diseases (Megahed et al., 2021). The ergonomic design layout and spatial arrangements in housing could compromise indoor comfort considering the relationship of the space planning and function. (Ismail et al., 2017)

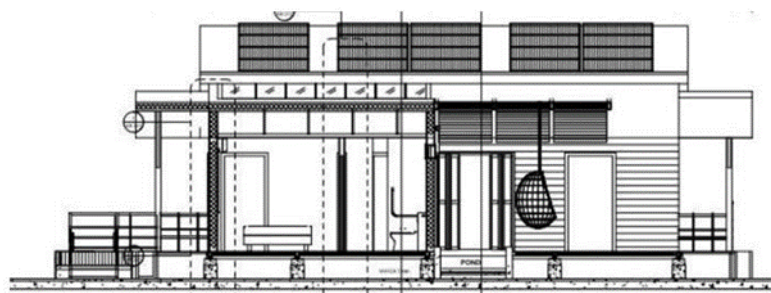


Figure 1: Open concept in housing scheme

Figure 1 displays the section of the open-plan home office design that enables cross ventilation and daylighting. The working environment suits the need for a comfortable environment when natural lighting is integrated into the design. Figure 2 illustrates the three modules as dwelling options during the outbreak. The modular construction depicts that the other parameter to measure human comfort and investigate the thermal condition of various building configurations is the surface temperature and the building facade at a critical orientation to provide a critical thermal condition (Abdullahi et al., 2021).

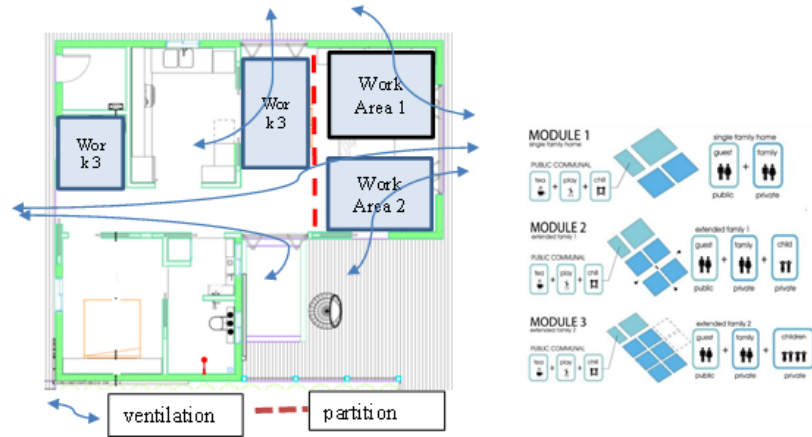


Figure 2: Internal layout with cross ventilation and design of open home-office design concept

Façade design and Overall Thermal Transfer Value (OTTV)

The indoor and outdoor environment depend on the wall of the building, which acts as a barrier and is an essential element in enhancing the thermal building performance. The energy performance of buildings is achieved at the minimum level when the thermal insulation and indoor temperature are improved. The significance of the OTTV is to measure the heat gain and the portion of the building where thermal energy is transferred or the thermal solar transmitted the heat gain through the building envelope. The OTTV concept describes that the building envelope is completely enclosed. The study formulated the calculation of OTTV based on a house with green walls at the side and palm oil trunk fibre as insulation at the wall. Using the formula, the heat conduction through walls and windows and solar heat gain could improve the average surface of solar radiation. The formula is stated as follows:

$$OTTV_i = 15\alpha (1 - WWR) U_w + 6 (WWR) U_f + (194 \times CF \times WWR \times SC)$$

Where α = solar absorption

WWR = window to wall ratio U_w = U-value of wall

U_f = U-value of window CF = Correction factor

SC = Shading coefficient

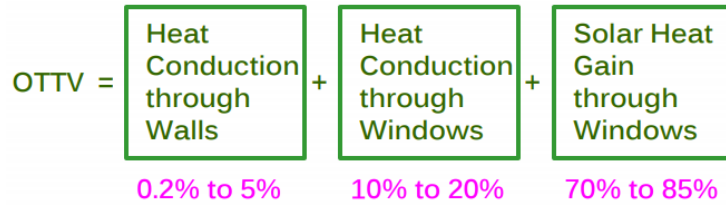


Figure 3: OTTV and heat conduction parameter
 (Source: MS1525:2007 Clause 5.2.2)

The heat conduction through walls is estimated between 0.2 to 5% to reach the thermal conductivity of the material. The conduction becomes lower if the thermal conductivity of the material is low. Meanwhile, the heat conduction through the wall is based on a window-to-wall ratio. The solar heat gain through the window is at 70 to 85% of solar energy to pass through the glass.

Table 2 : Thermal conductivity among the material

Material	Value (W/mK)
Hemp	0.038-0.040
EFB palm fiber	0.04
Coconut fiber	0.048
Wood fiber	0.04
Kenaf	0.061-0.065
Glass wool	0.036-0.038
Structural softwood or plywood	0.115

Source: Ahmad Marzuki, 2016

In Table 2, the thermal conductivity in the EFB palm fibre demonstrates that the property is significantly longer for high conduction among other materials. The fibre from plant waste with 0.04 U-value depicted the lowest U-value in Figure 4.

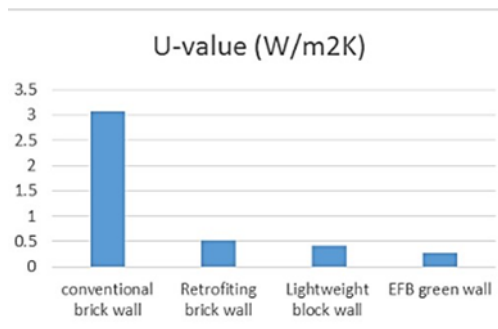


Figure 4: The U-Value comparison of wall profiles
 (Source: Husini et al, 2018)

Benefits of Green Wall to Environmental and Psychological Aspects

The green wall provides numerous benefits to the built environment in the environmental and psychological aspects. For environmental benefits, green wall facilitates in reducing indoor air temperature (Basher et al., 2016; Perez et al., 2014), minimizing the energy consumption for air conditioning (Perini et al., 2017), mitigating the urban heat island effect (Sheweka & Mohamed, 2012; Shafiee et al., 2020), enhancing the air quality, reducing indoor air pollution (Torpy & Zavattaro, 2018), and reducing noise pollution (Azkorra et al., 2015; Paull et al., 2020; Shushunova et al., 2021). Additionally, the green wall provides psychological benefits.

Apart from providing an aesthetic value to the environment, the visual contact with the green wall significantly impacts stress recovery and human well-being (Elsadek et al., 2019; Laage et al., 2019; Lotfi et al., 2020; Chan et al., 2021) and enhances students' cognitive skills (Van den Berg et al., 2017; Mccullough, Martin, & Sajady, 2018). To lower the OTTV, the specification of the opaque surfaces results in heat reduction. The selected insulation inside and variation of glass types provide an effective way to minimize the cooling load, leading to acceptable thermal performance. (Vijayalaxmi, 2010).

METHODOLOGY

The study performed a literature analysis in living concept concerning indoor-outdoor activities with the physical elements of a house during the pandemic and observation of indoor temperature that impact the cooling load. The test was conducted on a selected mockup house in Nilai, namely Mizanhome with an open plan layout to identify the indoor environment, activity, and energy consumption. Simulation tools were adapted to assess the thermal performance and temperature based on four orientations following a case study of a house located in Al-Makhtoum, United Arab Emirates (UAE), Dubai. The parameter for calculating OTTV was based on building design parameters: orientation and walling material. The opening based on the facade layer tested the temperature and cooling load when the open plan of a home-office layout was introduced in a housing scheme. The study also recorded the temperature when the window was opened and closed during the day and night.

RESULT AND DISCUSSIONS

The temperature in the building with insulation and building envelope forms resilience to drastic weather changes during the day and night, while the wall of the house was a cavity wall with organic insulation being installed in between the wall to act as insulation material. The organic insulation is made from compacted palm trunk residue using a special machine due to good thermal conductivity for the house. The thermal performance results in Figure 6 demonstrate a 25%

reduction of thermal heat gain inside the house when the integration of the wall and organic insulation is compared to external weather.

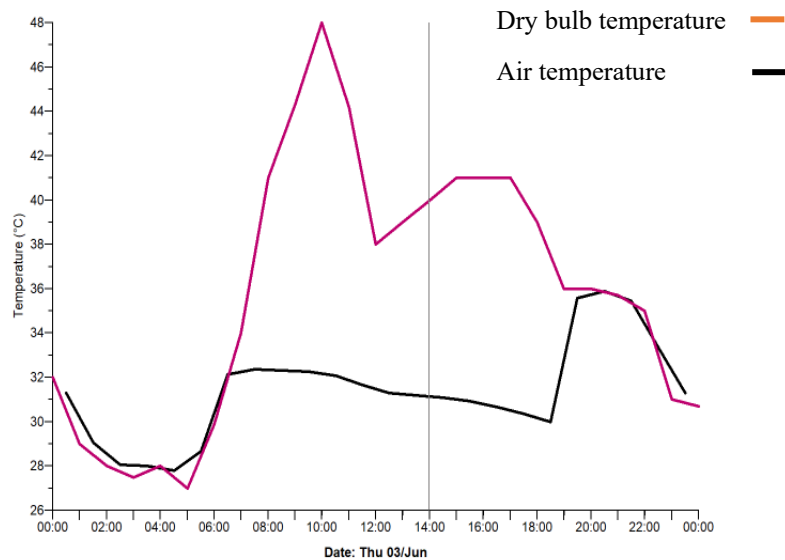


Figure 5: Air temperature and Dry bulb temperature

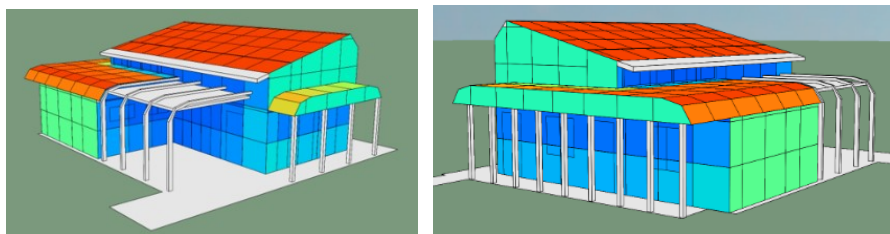


Figure 6: Thermal performance on West and East

Figure 6 depicts the solar heat gain from the orientation at the east and west facades. The passive strategy on the wall facade design was selected to adapt the insulation with the increase of 55% thickness from the standard wall design to provide a better thermal transmittance based on the building orientation. A complete annual weather data was acquired for the energy analyses. Weather was a primary driving force for the simulation and should closely reflect the real climatic conditions encountered by the building. The data must be in hourly time steps or shorter, provided that the simulation programmed can handle it.

The study used hourly weather data ARE_AL-MAKTOUM-IAP_411945_TYP.epw as the published ready-made weather file. Meanwhile, measured weather data sets from on-site measurements were not available. The

ideal solution was to compare results with weather reports as a general observation. The building form was modelled close to the architectural geometry of the building design. The form included the orientation and shape of the envelope, location and size of the windows, and zoning of the interior spaces. Several simplifications were applied to ensure a successful simulation with plausible results.

No solar-neutral simulation was considered as the form and orientation were fixed; hence the test did not require simulating the building at multiple orientations as only one simulation was necessary. Figure 8 illustrates the fenestration and window location in the solar home allowing sufficient daylight, particularly in the living, bedroom, and working areas. The illuminance level was between 90 to 130 lux level. Experimental work was performed on the insertion of an external screen to prevent direct sunlight indoors. The indoor lux followed the recommended lux for home, which is more than 110 lux.

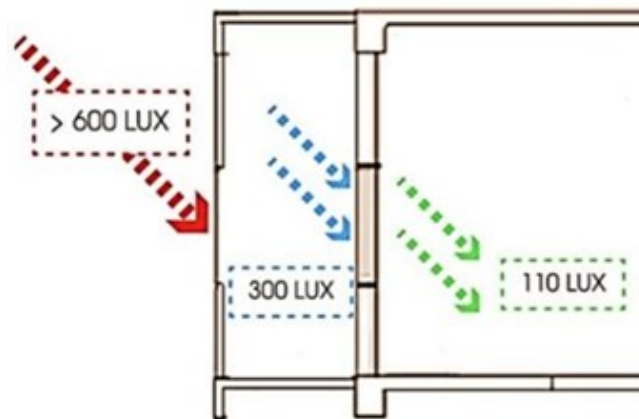


Figure 7: Daylight availability

OTTV CALCULATION BASED ON ORIENTATION

Table 2 reveals that the OTTV values for the house which faces the East orientation produced a higher value compared to the facade facing the North, West, and South. The OTTV value on the East orientation was 63.80 compared to the recommended OTTV value of 45, thus indicating high heat gain.

Table 3: Overall Thermal Temperature Value (OTTV) calculation based on orientation

SIDE	North	West	East	South
OPENING AREA	1.8 x 2.2 = 3.96 1.2 x 1.2 = 1.44	1.2 X 1.2 = 1.44 1.2 X 1.2 = 1.44 1.0 X 2.2 = 2.2 0.75 X 2.1 = 1.65	3.0 X 2.2 = 6.6 0.9 X 1.2 = 1.08 0.9 X 1.2 = 1.08	1.0 X 1.2 = 1.2 1.8 X 2.2 = 3.96
TOTAL m2	5.4	6.73	8.76	5.16
SIDE AREA m2	10.4 x 3.2 = 33.28	8.25 X 3.2 = 26.4	8.25 X 3.2 = 26.4	10.4 x 3.2 = 33.28
WWR	5.4 / 33.28 = 0.1623	6.73 / 26.4 = 0.255	8.76 / 26.4 = 0.3318	5.16 / 33.28 = 0.15514
α	0.55	0.55	0.55	0.55
U_w	0.37	0.37	0.37	0.37
U_f	0.4	0.4	0.4	0.4
SC	0.77	0.77	0.77	0.77
CF	0.9	0.94	1.23	0.92
FORMULA	$15 \alpha (1-WWR) U_w + 6 (WWR) U_f + (194 \times CF \times WWR \times SC$			
OTTV	24.767	38.695	63.80	21.986

Figure 8 depicts that the result of the simulation of the house was thermally performed, where only natural ventilation was present without an air-conditioning system, the thermal requirements, and the predicted indoor temperatures. Moreover, cooling loads decreased by 5 degrees even during peak hours between 3 to 6 pm. The observations by simulation data suggested that indoor temperatures were optimal when the air-conditioning in the house was switched on and set at 28 degrees Celsius to control humidity rather than cooling and mainly due to external ambient temperatures.

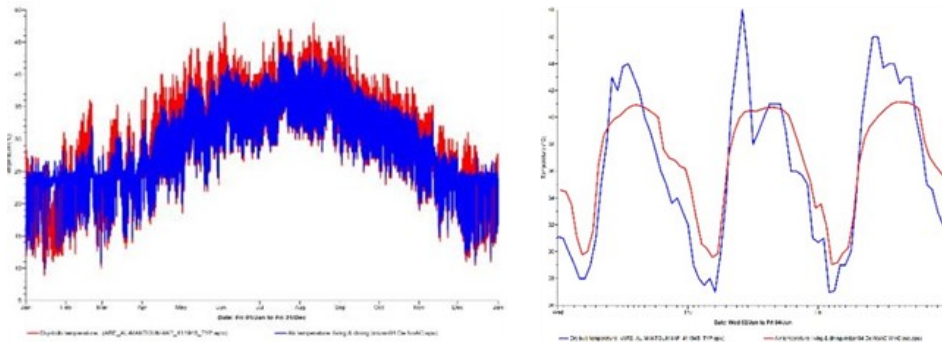


Figure 8: Passive analysis without air-conditioning system

CONCLUSION

The results revealed that the development of an open-plan home office design should incorporate passive strategies and orientate the building intelligently. The facade design significantly affected the thermal performance when insulating the wall with the fiber material reducing the thermal transmittance and heat gain without compromising thermal comfort. The thermal conductivity was critical to an indoor temperature where the reduction of 5 degrees Celsius during peak hours introduced the high performance of the building and maintained the air-condition at 28 degrees Celsius. The design parameters with shading coefficient based on the OTTV calculation depicted the bioclimatic response. The design determined the building envelope shape effect and ensured that the home office design during the pandemic achieved optimum efficiency. Therefore, the case study was categorized into the design of the building envelope and solar absorption efficiency where the basic criterion was environmental suitability and sustainability that produced significant results. The home-office layout modification and material selection demonstrated an excellent measure of OTTV even in the new layout of the home office design. Using the material of fibre for insulation and providing the window-to-wall ratio of 30 to 50% reduced the heat gain and fulfilled the study objective to provide a healthy indoor environment using passive strategies

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