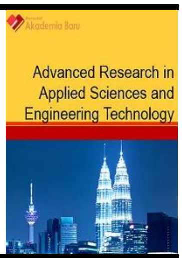
Penerbit Akademia Baru

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage: www.akademiabaru.com/araset.html
ISSN: 2462-1943



The Effectiveness of Envelope Design in High Rise Office Building using Exterior Wall Cladding as Green Technology Solutions in Malaysia's Urban Context

Open Access

Alice Sabrina Ismail[1,*], Hazrina Haja Bava Mohidin[1], Aminatunzuhariah Megat Abdullah[1], Mohd Nazim Ahyaruddina[1]

[1] Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia, UTM, 81310, Skudai, Johor, Malaysia

ARTICLE INFO

Article history:
Received 5 June 2019
Received in revised form 4 July 2019
Accepted 12 July 2019
Available online 21 July 2019

Keywords:
External wall cladding; building envelope; thermal comfort; high rise office

ABSTRACT

A comfortable work space is important to produce productive work performance among workers. In Malaysia, the condition of office environment and its related issues on thermal comfort are fairly new. Past studies shown that the increment of energy consumption in high rise offices tend to increase dramatically. This is because the consumption of air condition for cooling accounts in office buildings had increased from 40% to 60% in recent years and the total electricity usage for office units also rises intensely due to urban heat island (UHI) resulted from modification of land surfaces. The objective of this paper therefore is to investigate the conditions and problems of existing prominent high rise office in Kuala Lumpur which is IBM Plaza and Menara Mesin Niaga in the scope of thermal comfort as well as describes an integrated passive design approach to reduce the cooling requirement for high-rise office building through an improved building envelope design using green technologies like external wall cladding following the GBI standard. This paper also attempts to get the user perception towards their existing workspace. For this purpose, case study as research strategy is adopted using mixed methodology combining qualitative and quantitative method under the framework of interpretivism and positivism research paradigm. Findings indicate that external wall cladding made of composite aluminium provides much advantages to the user. This study is important because appropriate design principles by adopting appropriate building envelope made of suitable material addressing ecology issues will not only provide a comfortable living environment to the users but also established referential guideline for future designers and scholars whom interested in office design.

1. Introduction

In the Malaysian context, the Green Building Index (GBI) was introduced in early 2008 as rating tool for buildings namely in the public sectors to promote sustainability and to achieve the prescribed sustainable accredited standard [1]. Referring to past studies Samari *et al.*, [2], the GBI requirements however, are not fully implemented by many local designers and developers. This matter hence

* *Corresponding author.*
E-mail address: b-alice@utm.my (Alice Sabrina Ismail)

resulted to arising issues in the building industry which portrays buildings design that lack in energy and resources savings as well as built form that inharmonic with the local climate and surrounding environment. This indirectly led to significant non-operational savings and decrease of workplace productivity as well as lack of living comfort among users [3]. According to scholars Darus *et al*., [4], there are various approaches that can be adopted by construction sectors to conserve the environment involving usage of efficient energy, proper management of indoor quality environment, usage of recycle materials and renewable resources that minimize emission of toxic substance and waste as well as practical adaptation of innovative design with minimal building operational and managing costs. To achieve this the focus of this paper therefore is to identify possible solutions in relation to building materials and technology usage that can produce a sustainable office building. The scope of this paper is to highlight the utilization of appropriate construction materials like cladding for external walls to obtain maximum results for users' thermal comfort namely in high rise office building. The use of external building envelope is viewed as the best measure and precision to produce an environmentally friendly office building. The use of the external layer will produce a gap between the outer layer panel and the original surface. This gap indirectly will trap heat from flowing directly into the building and minimize the solar radiation as well as sunlight. According to building technologist [5], this external wall may be made of variety of material namely metal, stone or concrete depending on the suitability of the building design. Currently the use of this additional outer layer is namely viewed as an aesthetical element for decorative purposes rather than for functionality usage. Hence there is a need to improvise and innovatively utilize the usage of external walls for saving energy consumption in buildings [6]. There are two main objectives of this study. First, is to identify the most suitable external wall that can provide optimum effect for indoor thermal comfort. Second, is to highlight the importance of external wall for short and long term usage towards energy saving consumption in office buildings. For the benefit of the study and to fulfil the above objectives the next section will firstly define the meaning of building façade followed by discussion on external wall cladding and its purposes to strengthen the need of the study.

2. Building Façade and Its Role

Building façade can be defined as exterior side of a building comprising of rear, frontal or side of a built form. It can be in form of vertical or slightly inclined envelope of a building [8]. The façade of a building is often the most important aspect from a design perspective, as it sets the tone for the rest of the building which carries many function. According to scholars Letchford *et al*., [9], building façade is vital as it answers the need for four main reasons in building design. First for support requirements involving building resistance (strength), compability, durability and fire resistance. Second to fulfill comfort requirements encompassing of thermal control (insulation, thermal inertia, radiation control, ventilation and air tightness), moisture protection (rainwater or groundwater and capillary water tightness), hydrothermal, lighting (natural and blind control) and acoustic control [10]. Third is for complementary requirements that integrates building services [11], and for incorporating advertising elements [12]. Fourth, to serve as structural requirements for building stability and integrity. In brief, façade played an important role in determining the building design in terms of aesthetical influence, structural elements and for utilities purposes. However, the erection of building façade has direct impact for building's thermal comfort since façade is much vulnerable to the environmental conditions. Hence the selection of building façade type should be appropriate that responsive to the overall shape and orientation of the building [13]. To fulfil the need of thermal comfort in buildings interior, materials selected to cover the external façade known as wall cladding must be physically sound in which should not absorb heat but reflect it. To understand the role of external wall cladding next section will discuss this matter in depth.

1.1 Definition, Types and Characteristics of External Wall Cladding

The term 'cladding' generally refers to components that are attached to the primary structure of a building to form non-structural, external surfaces whilst wall cladding can be defined as the application of one material over another to provide skin or layer intended to control the infiltration of weather elements, or for aesthetic purposes on exterior building walls. According to Oleszkiewicz [14], external wall cladding is needed for eight main purposes like for creating a controlled internal environment, to protect the building from external conditions, to provide privacy and security, to prevent the transmission of sound, to provide thermal insulation, to create an aesthetical outlook for the external façade, to prevent the spread of fire, to generate an 'airtight' building envelope as well as to provide openings for access, daylight and ventilation.

Exterior building wall cladding may be done using metal elements comprising of choice of materials like aluminum, steel, zinc, aluminium and copper or from ceramic, stone, timber, weatherboard, fiber cement, brick or vinyl systems. However, the most common type used in the current context is from metal type. Of the lot, metal cladding type is traditionally preferred due to its features like flexibility, lightweight, durability and recyclable nature. Metal cladding can be very useful, as metal in general is typically very strong and durable, and its wide variety of types and finishes provide for aesthetic versatility. Metal cladding provide good performance in sound reduction that is, limiting the amount of noise getting in or out of a building. These metal profile sheets are manufactured in a range of corrugated and other profiles, such as trapezoidal, sinusoidal or half-round [15]. Metal profile sheets can be installed vertically, horizontally or diagonally, and are capable of being applied to curved facades and other complex shapes [16]. The installation of vertical metal profile sheets may give pleasing textural properties on the wall as it provides play of shadow effects. Horizontal profile shape however will give more scope for the expression of shape and colour to add interest to large building with simple overall geometric shape.

There are disadvantages and advantages if using this metal type from different materials as wall cladding. For instance, the use of steel as cladding material is viewed by many scholars as the most affordable but not durable. This is because steel required to be supply with hot-drip galvanised to provide a robust finish [17]. The adaptation of zinc on the other hand, is highly durable but its adaptation will weather to an unaesthetically-pleasing lead-like hue if left untreated [18]. Copper however is capable of achieving long lifespans, and requires very little maintenance but copper’s initial cost is higher than some other architectural metals [19]. Hence, for the benefit of this research, metal cladding from aluminium type will be discussed in depth. This is because, the usage of aluminium, is very lightweight, with a hard protective layer that protects against corrosion. In addition, aluminium systems can offer longevity, reasonable consideration towards thermal performance, good weather resistance and has strong structural integrity [20]. Nevertheless the adaptation of metal cladding for the purpose of increasing thermal comfort in buildings are likely unpopular reason adopted in the context of Malaysia as many designers and builders tend to apply the use of metal cladding for aesthetical purposes or as building accessories. Furthermore, there are no comprehensive studies in Malaysia that describes the usage of metal cladding namely in high rise office which relates to thermal comfort among occupants while the used of metal cladding is a much easier sustainable approach to be applied in buildings [21]. This study will look this matter in depth by studying two prominent office building in Malaysia that applies different types of wall cladding

– metal (representing aluminium material) and ceramic as comparison to develop new framework approach for future reference to highlight the usage of metal wall cladding from aluminium type as design solution for both aesthetics and thermal comfort purposes.

2. Methodology

This research adopted mixed methodology combining qualitative and quantitative method under the framework of interpretivist and positivism research paradigm. Data collection method was on two selected prominent high rise offices which are the IBM Plaza and Menara Mesin Niaga. Justification for case study selection is based upon criteria that is the prominent office high rise building in Malaysia designed by Ken Yeang and categorized by scholars as bioclimatic high rise. This is important for evaluating the overall performance of the 'bioclimatic envelopes' in terms of energy use, interaction with daylight and heat gain and occupant assessment of internal environments under the Malaysian climate.

The research was conducted using scientific tools which is the Kestrel Weather tracker to measure the office interior involving level of wind chill, humidity and temperature. These measurements were vital to determine the heat level index. Readings were taken during the month of March as it is considered as the hottest month in Kuala Lumpur with an average temperature ranging between 28°C minimum to 36°C maximum. Readings for both building were taken eight times at duration of every 15 minutes during weekend and weekdays. Readings were done during hot weather when temperature ranges from 30 degree Celsius and above from noon till evening because during this period heat gain was to be known at the highest peak. To obtain the readings, point of location for measurement was in the interior office space but at 5m radius from the outer wall façade. This location was considered appropriate because thermal effect effectiveness may be well detected within this range to provide reasonable readings for the study [22]. In addition, the determination of point of measurement was also according to the following characteristics – point of reading was situated at the nearest distance to the external wall from the interior of office space and the selection of external wall is the one that faces the sun path movement as in Figure 1. To support data collection from scientific tools, direct observation and questionnaires were also conducted to gather data on the user comfort in their existing workspace.

To conduct the questionnaires, 50 office workers were chosen. Justification for the number of sampling size were determined in reference to maximum number of occupancy load that occupies the studied office space as well as based upon the benefits of Central Limit Theorem that highlights adequate size of finite population [23]. In the questionnaire all relevant aspect of occupants' satisfaction with indoor environment are addressed. The questions addressed properties relating to workplace like indoor air quality and velocity, temperature and humidity. Questions were answered within a 5-point Likert-scale by the participants. Observations on the hand, were done based on three main indicators which were on the understanding of the properties that make up the external wall façade in terms of material usage, its suitability of placement location and methods of construction. Findings from the results were analysed using integrated and explanation building approach for a comprehensive understanding. Figure 2 shows the flow chart to be followed to achieve the desired output of this research.

Penerbit Akademia Baru

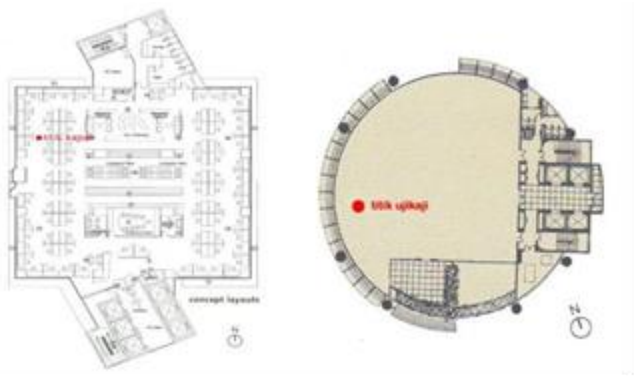


Fig.1. Location point of measurement

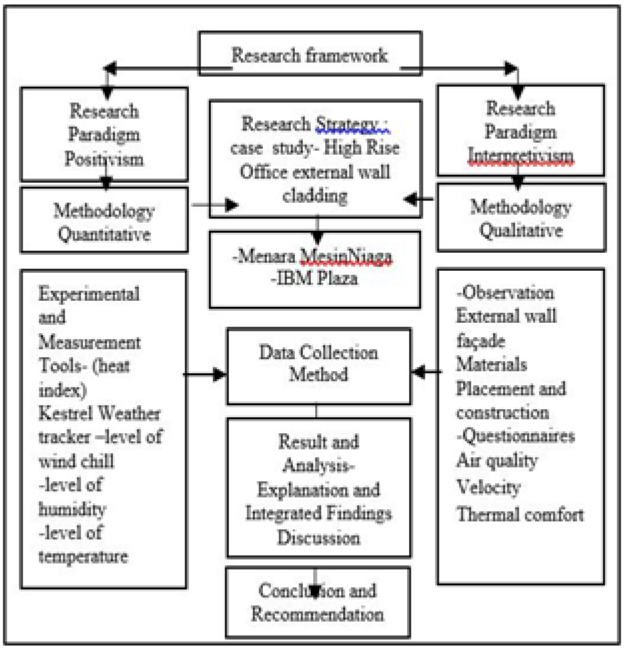


Fig. 2 Research framework and process flow

3. Results and Discussion

Case study – IBM Plaza (ceramic cladding)

IBM Plaza which is a commercial office building was built in year 1985 and comprised of 24 floors. The building is 112 meters in height and is located at Jalan Tun Muhd Fuad in Kuala Lumpur. The main architectural features of this building portrays response towards ecological design.IBM Plaza has a hybrid form and its top tower design is pitched as an abstraction of the traditional Malay house form. The overall massing of the building configuration consists of an office tower linked by a curvilinear bridge to a two-storey crescent-shaped lower block, housing a restaurant and a food court. The typical floor plan is orientated towards the north-south axis in relation to the sun's path. The external wall façade is covered by ceramic wall cladding and has vertical landscaping in the form of a diagonal garden that climbs one side of the building to the fourteenth storey, where a landscaped void-deck occurs. The overall building structure adopts steel reinforce concrete system. Refer Table 1 and Table 2

Case study – Menara Mesin Niaga (composite aluminium cladding)

Menara Mesin Niaga which is situated at Subang Jaya was completed in year 1992. The building is sited beside the highway towering above unplanned environment comprised of an open lake as well as existing building structures such as residential complexes, townhouse, mosque and office buildings. The Menara Mesin Niaga which functioned as IT office building consists of 15 storey with an area of 12,345 square meters. This building which is 63 meters in height adopts modernist architectural style and ecology design as its main approach. The building structure is divided into tripartite section comprised of raised green base, ten circular floors of office base with terraced garden balconies and external louvers for shade and is topped by a spectacular sunroof arching across the top floor pool. The image making of this building by the architect is to showcase a building that represent commercial success and projects the client role as successful contenders in the IT business. The entire building structural system are made of reinforced concrete structural frame and brick infill. Refer Table 1 and Table 2.

Findings from both case study above in Table 1 and Table 2 shows that Menara Mesin Niaga which used external wall cladding made of composite aluminium provides much advantages to the user unlike IBM Plaza which adopts ceramic wall as its external wall cladding. The usage of external wall cladding from composite aluminium proven to increase the level thermal comfort among occupants in Menara Mesin Niaga building. This is because the external wall cladding made from composite aluminium act as insulation layer between the internal and external wall which infiltrate heat gain from directly enters the building interior space.

Unlike the IBM Plaza which adopt ceramic external wall it allows direct penetration of heat into the layers of internal wall and building structure which resulted to an increment of indoor room temperature. Findings indicates that room temperature taken during the early stages of research in Menara Mesin Niaga only tend to change in range of 2.4°C within 2 hours' time even though when the positioning of the sun is directly located on top of the building till sunset. This shows that only slight increase of temperature occurs in Menara Mesin Niaga from noon till evening differ from Menara IBM which portrays massive difference in temperature readings that is slightly higher with a difference between 2°C to 6°C. Wind chill and humidity level in the Menara Mesin Niaga interior office space also indicates evenness throughout the measurement reading period from noon till evening. In brief, from the conducted questionnaires' most of occupants in Menara Mesin Niaga obtain full general satisfaction and individual satisfaction compared to IBM Plaza users whom are mostly not in the satisfaction parameters.

4. Conclusion

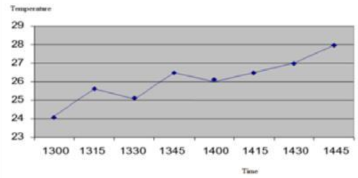
In conclusion, the results from this experimental study portrays that the usage of building materials affects the rate of indoors thermal comfort. This is because the usage of different materials for external wall records different temperature readings for indoors areas. From the conducted study clearly shown that the design of façade outer layers plays an important role that effects the indoor environment. The exterior façade may become insulation to the building that filters the heat or otherwise. Henceforth, the external building façade should not be viewed in terms of aesthetical needs but the usage should also be taken into consideration as protective device to obtain thermal comfort in buildings. The design of the outer layer façade involving suitability of material selection, usability and functionality should be taken into account by designers. In addition, other aspects like building functionality, internal and external conditions of building, maintenance and structural requirement should also be considered. This will contribute in determining the health, comfort and well-being of office inhabitants.

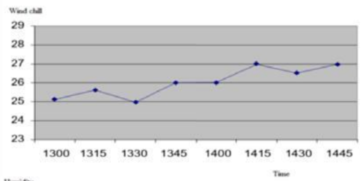
Table 1
Findings from quantitative analysis

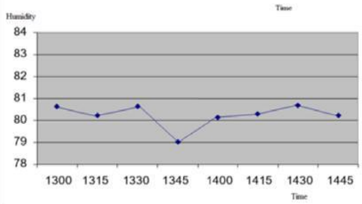
Case study	Data Collection Methods (Quantitative)	Findings in relation to temperature are shown from 1pm to 3 pm because these hours are considered as the hottest period in a day, however readings for IBM plaza and Menara Mesinniaga indicates that there are only differences between 0.5 to 1 °C from 3pm till 5pm from the early readings taken at 1 pm .
A- IBM Plaza	Experimental and Measurement tools- Temperature, wind chill and humidity	(see data table and charts below)
B- Menara Mesin Niaga		(see data table and charts below)

A- IBM Plaza

TIME	1300	1315	1330	1345	1400	1415	1430	1445
(temperature)	24.1 °C	25.6 °C	25.1 °C	26.5 °C	26.0 °C	26.5 °C	27.0 °C	28.0 °C
(wind chill)	25.2 °C	25.5 °C	25.0 °C	26.0 °C	26.0 °C	27.0 °C	26.5 °C	27.0 °C
(humidity)	80.7 %	80.1 %	80.7 %	79 %	80.0 %	80.2 %	80.7 %	80.1 %

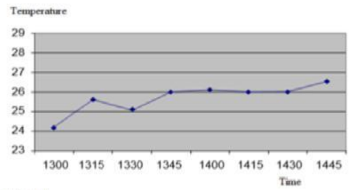


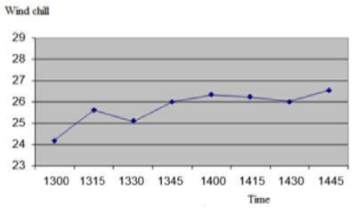




B- Menara Mesin Niaga

TIME	1300	1315	1330	1345	1400	1415	1430	1445
(temperature)	24.1 °C	25.6 °C	25.1 °C	26.0 °C	26.1 °C	26.0 °C	26.0 °C	26.5 °C
(wind chill)	24.2 °C	25.5 °C	25.2 °C	26.0 °C	26.3 °C	26.2 °C	26.0 °C	26.5 °C
(humidity)	81.7 %	81.7 %	81.7 %	80 %	81.7 %	81.0 %	81.0 %	81.7 %





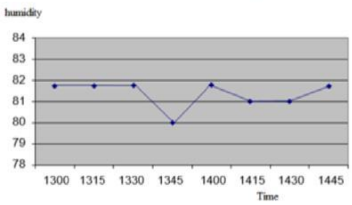
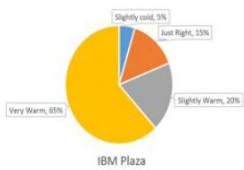
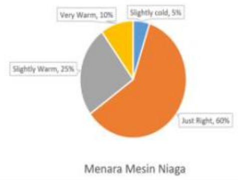


Table 2
Findings from qualitative analysis

<table>
<tr><td>Data Collection Methods (Qualitative)</td><td colspan="2">Findings in relation to occupants thermal comfort and satisfaction without mechanical ventilation provided (air conditioning) in the interior office space to identify the effects of adapting external wall cladding</td></tr>
<tr><td>Questionnaire</td><td colspan="2">a)Indoor air quality (without air conditioning)
Are you satisfied with the indoor air quality and overall indoor climate? (this question correlates with occupants feeling in terms of wellness; alertness; mode of work concentration and mood situation).</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td></td><td colspan="2">b)Indoor temperature and humidity level (without air conditioning)-
How do you feel inside the office space during the afternoon till evening? (this question correlates with occupants thermal sensations in terms of work comfort. If the subjects are in the category of very warm and slightly warm they feel stuffy and sticky hence demand for stronger air movement). The just right category indicates neutral and positive votes which shows that the subjects are comfortable in their work space.</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
</table>

References

[1] Index, Green Building, and G. B. I. Malaysia. "Green Building Index." *Retrieved from Malaysia* (2013).

[2] Samari, Milad, Nariman Godrati, Reza Esmaeilifar, Parnaz Olfat, and Mohd Wira Mohd Shafiei. "The investigation of the barriers in developing green building in Malaysia." *Modern Applied Science* 7, no. 2 (2013): 1.

[3] Bin Esa, Mohd Reza, Mohd Arif Marhani, Rostam Yaman, A. A. H. N. H. Noor, and Hamimah Adnan Rashid. "Obstacles in implementing green building projects in Malaysia." *Australian Journal of Basic and Applied Sciences* 5, no. 12 (2011): 1806-1812.

[4] Darus, Zuhairuse Md, Nor Atikah Hashim, Elias Salleh, Lim Chin Haw, AK Abdul Rashid, and SN Abdul Manan. "Development of rating system for sustainable building in Malaysia." *WSEAS Transactions on Environment and Development* 5, no. 3 (2009): 260-272.

[5] Woolley, Tom, and Sam Kimmins. *Green Building Handbook: Volume 2: A Guide to Building Products and their Impact on the Environment*. Routledge, 2003.

[6] Huat, Ng Ban, and Zainal Abidin bin Akasah. "An overview of Malaysia green technology corporation office building: A showcase energy-efficient building project in Malaysia." *Journal of sustainable development* 4, no. 5 (2011): 212.

[7] Kolokotroni, Maria, Syreeta Robinson-Gayle, Stephen Tanno, and Andrew Cripps. "Environmental impact analysis for typical office facades." *Building Research & Information* 32, no. 1 (2004): 2-16.

[8] Radhi, H. "On the optimal selection of wall cladding system to reduce direct and indirect CO2 emissions." *Energy* 35, no. 3 (2010): 1412-1424.

[9] Letchford, Chris W., and H. Scott Norville. "Wind pressure loading cycles for wall cladding during hurricanes." *Journal of wind engineering and industrial aerodynamics* 53, no. 1-2 (1994): 189-206.

[10] Galbusera, M. M., J. de Brito, and A. Silva. "Application of the factor method to the prediction of the service life of ceramic external wall cladding." *Journal of Performance of Constructed Facilities* 29, no. 3 (2014): 04014086.

[11] Ozkahraman, H. Tarik, and Ali Bolatturk. "The use of tuff stone cladding in buildings for energy conservation." *Construction and Building Materials* 20, no. 7 (2006): 435-440.

[12] Anderson, John Maxwell, and J. R. Gill. *Rainscreen cladding: a guide to design principles and practice*. Butterworth-Heinemann, 1988.

[13] HO, Daniel CW, S. M. Lo, C. Y. Yiu, and L. M. Yau. "A survey of materials used in external wall finishes in Hong Kong." *ol. 15 Issue 2 December 2004* (2004).

[14] Oleszkiewicz, Igor. "Fire exposure to exterior walls and flame spread on combustible cladding." *Fire Technology* 26, no. 4 (1990): 357-375.

[15] SCHAUPP, W. "EXTERNAL WALL CLADDING." *FLIESEN PLATTEN Fliesen Platten* 38, no. 7 (1988): 62.
[16] Cheng, C. Y., Ken KS Cheung, and L. M. Chu. "Thermal performance of a vegetated cladding system on facade walls." *Building and environment* 45, no. 8 (2010): 1779-1787.
[17] Tzempelikos, A., M. Bessoudo, A. K. Athienitis, and R. Zmeureanu. "Indoor thermal environmental conditions near glazed facades with shading devices–Part II: Thermal comfort simulation and impact of glazing and shading properties." *Building and Environment* 45, no. 11 (2010): 2517-2525.
[18] Balocco, C., G. Grazzini, and A. Cavalera. "Transient analysis of an external building cladding." *Energy and Buildings* 40, no. 7 (2008): 1273-1277.
[19] Joudi, Ali, Harald Svedung, Chris Bales, and Mats Rönnelid. "Highly reflective coatings for interior and exterior steel cladding and the energy efficiency of buildings." *Applied energy* 88, no. 12 (2011): 4655-4666.
[20] Ozel, Meral. "Thermal performance and optimum insulation thickness of building walls with different structure materials." *Applied Thermal Engineering* 31, no. 17-18 (2011): 3854-3863.
[21] Lam, Joseph C. "Energy analysis of commercial buildings in subtropical climates." *Building and Environment* 35, no. 1 (2000): 19-26.
[22] Athienitis, Andreas K. *Thermal analysis and design of passive solar buildings*. Routledge, 2013.
[23] Nuanally, J. C. (1967). Psychometric Theory. McGraw-Hill, New York: 355.