International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 03 – Issue 05 || May 2018 || PP. 181-189

The Shipping Container as Commercial Building: The Process of Construction and Thermal Comfort Conditions

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Abstract: Building made of shipping container as a basic material is still rare in Indonesia. It is only used to facilitate small activities such as house and shop. In fact, the price is quite reasonable; it can fulfill the needs of the building in Indonesia, such as housing. This study aims to assess the feasibility of the use of shipping container from planning, design, construction up to occupation including of thermal comfort which is used as a commercial facility especially pet salon. The building consists of two floors, where the first floor serves as lobby area and store, while the second floor used as raising pet with the total area 170 m2. The building is located in the Southern Jakarta and adjacent to other commercial facilities. The study was conducted through observation and field experiment, especially the measurement of the thermal conditions. The study also carried out by computer simulation (PMV) to predict thermal comfort. The research result shows that generally the whole process of construction in line with the blueprint. However, the insulation used of the building is not fit. This is indicated by the thermal comfort prediction of the office that ranges from 1 – 2, that is from neutral to warm. It means that the thermal conditions is not neutral / comfort to the occupants

Keywords: Shipping container, Thermal environment, Thermal comfort, PMV, Pet salon

1. Introduction

The Government of Indonesia has two main focuses in the national development process, namely infrastructure development and human resources. However, the government is still concentrating on infrastructure development in order to compete with other countries.[1]. During the period 2015-2019, infrastructure development targets include the construction of 1,000 kilometers of toll roads, the construction of new 2,650 kilometers of roads, the construction of 65 dams, and the provision of 1 million houses. [2].

With regard to housing construction, the total housing need by 2030 is estimated to reach 29.6 million units. If the assumption of an average housing supply is 400 thousand units per year, then it is estimated at 2030 new home supply is 8 million units or only 27% of the needs. With a limited supply, it is predicted that there will still be a 20.6 million shortage of housing supply (backlog) of 2030 units from its current position of 15 million units. [3].

Recently, housing procurement most are provided independently by the community either builds themselves or rent to other parties. The main constraint faced by the community in general is the affordability of home financing. On the other hand, mortgage loans from banks require a variety of requirements that not every party can get easily and interest rates are not cheap. Housing and residential development on a large scale will always be faced with land issues, which are increasingly scarce and expensive in urban areas. Another factor is the production of building materials and its distribution closely related to price, quantity and quality and mastery of the technology of housing development by the community.

One of the materials that can be used as an alternative housing development is container. Usually, Containers have been used only as tools for transporting and delivering goods. However, the container can be processed into other functional objects one of which becomes a building module. Precision shape and size of container and strong structure make container can be used as alternative material to make building without need big foundation.

2. Literature Survey

The use of containers as building materials is not common in Indonesia. They are only used for individual buildings such as cafés, restaurants, and libraries. Their use are more common in Europe and America. In these countries, container material is widely used to build public buildings such as student dormitories and low-cost apartments due to abundant supply of raw materials and cheaper material prices than stone and wood materials. [4].

Some people in Indonesia consider containers unfit for housing because of their limited size, heat and lack of prestige [5]. To further popularize the use of containers, then research on the application of container as

a building carried out. Research on the division of space for educational / library facilities are carried out [6]. Research of container applications for 3 star hotels is also conducted [4]. The research on emergency residence facility is conducted [7]. Then Lianggono Susanto [8] examines the use of containers for libraries. General facilities (Retail design) are also studied [9] in Surabaya. The study about thermal state is still limited. This research will focus on field measurements of the thermal performance and thermal comfort of container buildings.

The benefits that can be taken with the considerable amount of the container is its use as an ingredient of building. Indonesia still lacks tens of millions of homes to meet the needs of its people. Based on the data from the Central Statistics Agency [10], the gap needs and the availability of the house (backlog) in 2014 reached 15 million units. This means that there are about 15 million households who do not currently own a house, or 60 million people. The backlog of houses continued to rise from year to year. In 2010, the backlog of houses stands at 13.6 million units. Until this year, the figure had increased by 10.29 percent. It is estimated that five years later, the backlog is expected to 'explode' to reach 17 million households, equivalent to 68 million Indonesian people who do not have appropriate housing [11]. Minister for Public Housing fixed targets of the National Medium Term Development Plan (RPJMN) government for the housing sector was 1.35 million units, but housing budget per year is only enough for 100 thousand housing units.

3. Research Elaborations

The container building in this study is intended for pet care services business. This building is located on Arteri Permata Hijau Road no. 5, West Jakarta. It has various facilities such as: lodging pets, especially cats and dogs, and accessories food store, cafe, swimming pool etc. This building has a ground floor area of 120 m2 occupies a land area of 906 m2. While, the total building area is 207 m2.

This study was conducted simultaneously and almost all of the room is using a container plate. The first floor there are two distinct areas, the first area includes Lobby, Store, and a toilet with an area of 50 m2. While, the second area consists of washing grooming and it has an area of 32 m2. To the second floor there are five rooms / areas, the first room is the office area of 11 m2, paint room hotel (inn cat) area of 13.6 m2. Dog room hotel (dog's inn) has the area of 19.2 m2, Cafe space has the area of 28 m2 and corridor with an area of 11 m2. Time measurement is done for 3 days and is done in a day for 11 hours of 09.00 s / d 19:00, measuring data retrieval is taken at intervals of 1 hour.

Besides using building measurements, there is also calculation using thermal comfort simulation program. This program can be accessed on the internet site at any time, while the values that must be entered are: air temperature, air humidity, wind speed, temperature radiation, type of activity and types of clothing so get massive value PMV.

4. Result and Discussion

4.1 Design process

The process of planning and design was conducted in the office consultant. There are three facilities in the project provided, that is public, semi public and private zoning. Public zoning is located on the ground floor altogether with semipublic. On the second floor, there are semipublic and private. The public zone consisted of lobby and store while the semipublic zone are washing, grooming, pool, services and toilet. Moreover, in the second floor there are corridor, cafe, second floor terrace, dog and cat hotel and the rest is office. Figure 1-2 shows the floor plan of the building

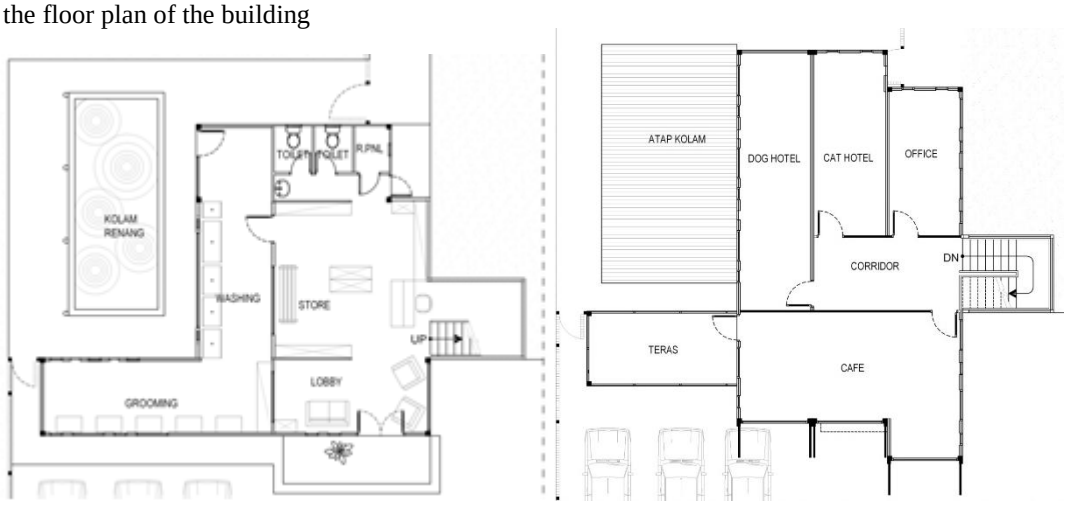


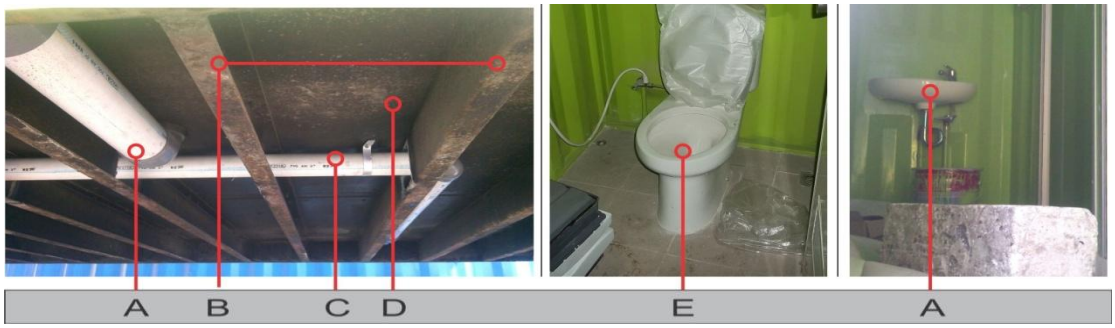
Figure 1-2. Ground floor and second floor plan of the pet salon (Courtesy: Magnus Cipta Estetika, Pte.Co)

4.2 Construction process

The construction work started from June to Jan 2014 to January 2015. Cutting the wall plates are customized needs, such as making opening doors, windows and any other opening in the opening need additional reinforcement as hollow steel frame 20mm x 40mm so that no deformation at plate the wall. (Figure 3 and 4). The installation of utilities such potable water, waste and black water systems are also equipped in building (figure 5 and 6). After installing the utilities, the finishing is carried out such as: painting (Figure 7 and 8). This is done after putty base on the wall. After all finishing works finished, the container is put on the foundations. The ground surface is flatted. The units of container for second level are also arranged. Furthermore, the glasses for window and or doors are installed.

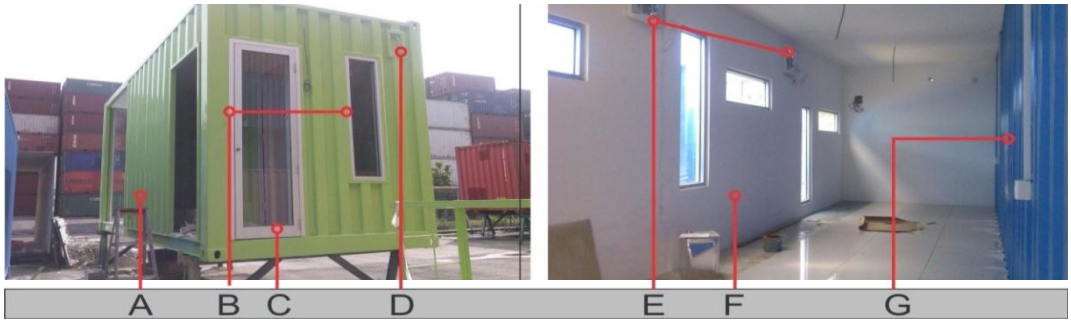
A. Hollow frame 40x40 mm
B. Glazing 6mm
C. Aluminum Frame 3"
D. Glasswool density 24 Kg/m3, 50 mm thick.
E. Gypsum board 9mm

Figure 3 - 4. Installation of door, openings and interior finishing (Courtesy: Magnus Cipta Estetika, Pte.Co)



A. Waste water pipeline
B. Black water pipeline
C. U Chanel 100mm x 75 mm stiffening (existing)
D. Playwood / multiplek 12 mm
E. Closet
F. Sink

Figure 5 - 6. Installation of pipeline utility and fittings (Courtesy: Magnus Cipta Estetika, Pte.Co)



A. Exterior wall with oil paint glossy finish
B. Aluminum 3" frame
C. Aluminum door
D. Holes for tuvur cable
E. Exhaust fan
F. Container interior with glasswool insulation and gypsum finish interior paint
G. Interior partition using a plate container

Figure 7 - 8. Finishing work for exterior and interior (Courtesy: PT. Magnus Cipta Estetika, Pte.Co)

Figure 9 - 10. Assembly and finishing of the building in the field (Courtesy: PT. Magnus Cipta Estetika) (Courtesy: Magnus Cipta Estetika, Pte.Co)

Red brick installation is done after the container is ready. Installation of red brick like in general, prior to the installation of red brick that is making the foundation stone. Stairs using material steel u channel 100 x 75, Finish Black matte paint, while for finishing interior brick exposure using white oil paint.

4.3 Thermal comfort predictions in the first floor

The first measurement conducted in the first floor (lobby, store and toilet). The results show that the air temperature in the room (lobby, store and toilet) in the morning of air temperature indicates (28 ° C) and surface temperature (28,5 ° C), air temperature at day time touching number (28 ° C) and the surface temperature reaches (29 ° C), in the afternoon the air temperature begins to decrease until it reaches the temperature limit (27 ° C) and the surface temperature reaches (28 ° C) while the lowest temperature is encountered at night (25 ° C) , 5 ° C) and the surface temperature reached the lowest point (26 ° C). The highest fluctuation for average air humidity in the lobby space, store, toilet is highest in the afternoon (71.5%).

When referring to the standard required by ASHRAE (1992) recommends a comfortable temperature limit of 22.5 ° C to 26 ° C for the summer. However, referring to research conducted by Karyono, et. al. (2015) states a comfortable temperature limit of Indonesia 24.9 ° C to 28 ° C [12]. Air temperature in the Lobby room, store & toilet is the highest is 28 ° C at morning and noon, so it is still comfortable for the body. Meanwhile, according to Mangun wijaya (1981). Comfortable humidity for the body in the tropics is 40% to 70%. The air humidity in this space was also highest in the afternoon at 71.5% slightly higher than the reference from Mangunwijaya.

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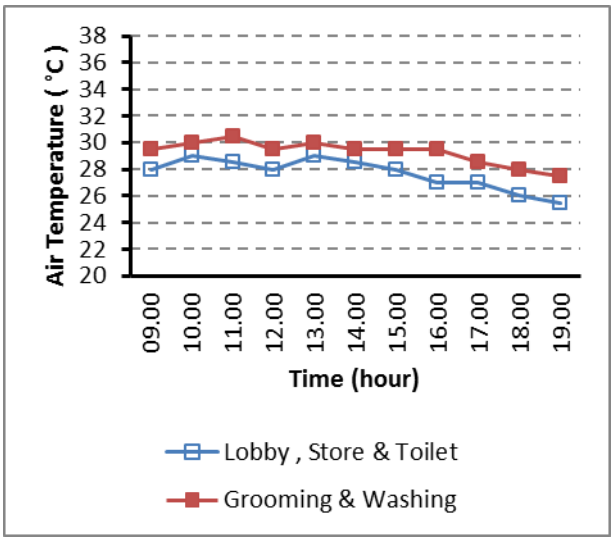


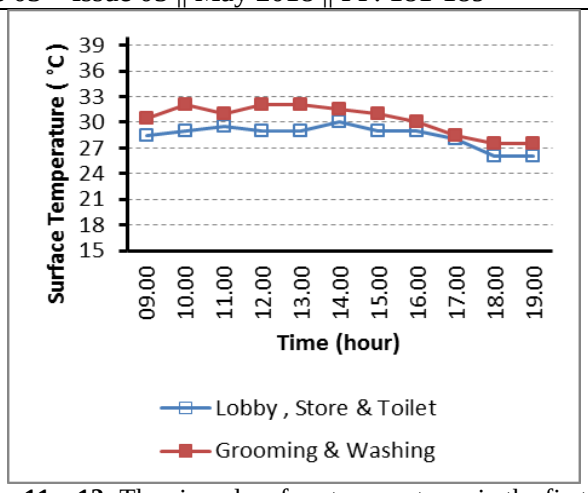


Figure 11 – 12: The air and surface temperature in the first floor

According to the calculation by CBE Thermal Comfort Tool, the conditions in the lobby, store, and toilet are the highest value reached during the day at 10.00 am, 11.00 pm, 13.00 p.m. and at 14.00 p.m. This is in because at that time the sun has begun to rise, so that solar radiation causes heat. In the room there is no air vents, just rely on artificial air conditioning. In this room there are 2 units of AC according to the calculation of the ac requirement this room is less to meet the needs of its air conditioner.

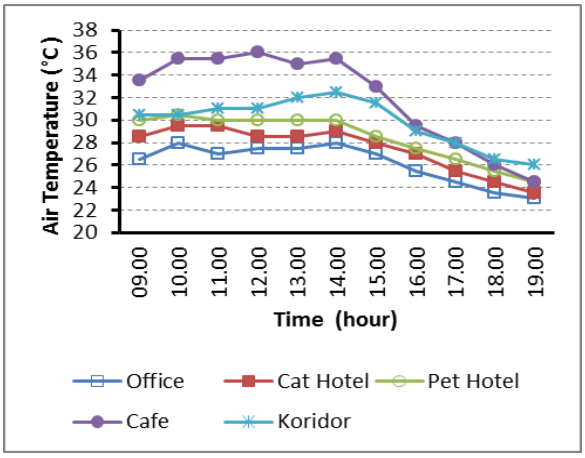
The second measurements are indoor Washing and Grooming. The results shows that the temperatures in the mornings (29.5 °) and the surface temperature (30.5 ° C), the highest temperature encountered during the early afternoon, reaching (29.5 ° C) and surface temperature (32 ° C), in the afternoon the air temperature starts to decrease reached (28 ° C) and the surface temperature is reached (28.5 °), to its lowest temperature encountered during night time (27.5 ° C) and the surface temperature reaches (27.5 ° C). Average humidity is reached (72%).

The air temperature in the room washing and grooming that could be accepted by the human body reached in the late afternoon to evening where the temperature ranges at 28^0C to $27{,}5^0$C. However, according to Mangun wijaya (1981), the comfortable humidity of the body in the tropics is from 40% to 70%. The average temperature is not comfortable for cats and dogs, whereas the comfort temperature according to the AVMA (2008) in the range $15{,}5^0$C - $26{,}6^0$C.

From thermal simulation, the value of PMV at 09.00 WIB s / d 16:00 pm value of PMV is high so the condition of the room is less comfortable to the body. The value PMV lowest at 17.00 p.m. to 19:00 p.m (warm ambient conditions). This is because in the morning until noon indoor washing and grooming take longer receiving solar radiation. There were vents in the area of glass washing, so that the light is let in the sun too long. There are two units of air conditioning with 1 hp each. According to calculations, the rooms need 2½ hp. air conditioning.

4.4 Thermal comfort predictions in the second floor

The measurement that is the office, cat hotel, pet hotel, café and corridor in the second floor and is as follows



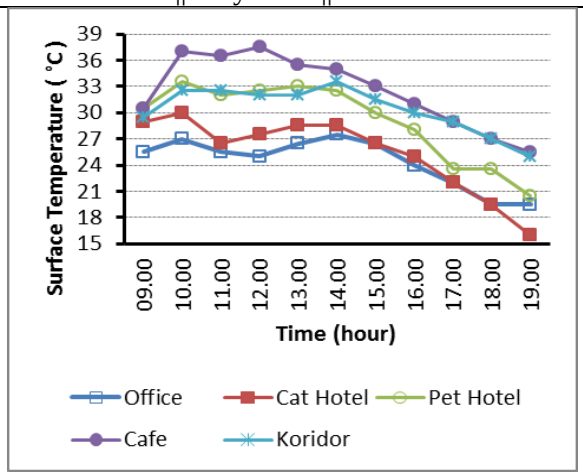


Figure 13–14: Air and surface temperature in the second floor

In the office, shows that in the morning the air temperature reaches 26,5^{0}C and surface temperature (25^{0}C). Approaching daytime, temperature reached 27^{0}C and surface temperature 25^0. In the afternoon, the air temperature and the surface temperature decreased to (24,5^{0}C and (22^{0}C). At night, air temperature decreased to 23^{0}C and the surface temperature reaches to 19,5^{0}C. However, the highest air humidity found in the morning reached (64%) and lowest humidity at night (50.5%).

When referring to the research conducted by Karyono (1993), the Indonesian comfort temperature range is 24.9°C to 28°C. Temperatures in the office space could be accepted by the body where the temperature ranges 23^{0}C to 28^{0}C. Meanwhile, according to Mangun wijaya (1981). humidity comfortable for the body in the tropics is 40% to 70%. The air humidity at that moment still under 70%.

In the cat hotel, the air temperature reach 28,5^{0}C) and surface temperature reach 29^{0}C in the morning. At the meantime during the day, the air temperature reaches 28,5^{0}C and surface temperature 29^{0}C. In daytime, air temperatures reaches 28,5^{0}C and surface temperature reached 27,5^{0}C. In the afternoon the air temperature decreased to 25,5^{0}C and surface temperature to 22^{0}C. At night, air temperature reached its lowest point at 23^{0}C and surface temperature at 19^{0}C. Humidity room air is the highest found in the morning (66%) and the lowest humidity at night (50.5%).

So the air temperature in cat hotel in the morning until noon cannot be accepted by human body (and cat) where the air temperature reached 29^{0}C. During the day until late afternoon thermal environment could be accepted by the body where the temperature range up to 28,5^{0}C. The humidity that made comfort to the body in the tropics is 40% to 70%. Humidity at that moment is still under 70%. According to the AVMA temperatures acceptable for the body of cats and dogs occurred in the afternoon until the evening on ^{0}C range of 23.5 - 25.5 ^{0}C. Whereas, the humidity in the room is still comfortable for cats and dogs.

According to the CBE Thermal Comfort Tool the PMV value at 09.00 a.m. to 10.00 p.m the is in the range of hot whereas the PMV is warm found at 11.00 p.m. to at 16.00 p.m. The neutral (not hot nor cold) found at 17.00 p.m. to 18.00 p.m. While the perception of cool found at 19.00 p.m. This is because this room is flanked by two containers, so in this room in the morning start to be hot caused by heat transferred by solar radiation from the dog hotel. If the position of the sun began to sink to the west the lower air temperature caused flanked by containers from both side.

In the dog hotel, the air temperature reached (30^{0}C) and surface temperature (30,5^{0}C), during the day the temperature was still (30^{0}C) and surface temperature (32,5^{0}C), in the evening air temperature decrease of up to (26,5^{0}C) and surface temperature (23,5^{0}C), while at night time air temperature reached (24,5^{0}C) and surface temperature (20,5^{0}C). The highest moisture is found in the morning (66%). while the lowest humidity encountered during night time (50.5%).

So the temperature of the air in a dog hotel in the morning until late afternoon cannot be accepted by the human body where the air temperature reaches 30,5^{0}C while in the afternoon until the evening 24,5^{0}C to 28,5^{0}C, so it is still accepted by the human body, air humidity in this space throughout the day is still below 70%. Temperatures can be in acceptable by the body of cats and dogs occurred in the afternoon until the evening on the range 24,5^{0}C - 26,5^{0}C, while the air humidity is still comfortable for the body of a cat and dog
According to the calculation using CBE Thermal Comfort Tool, the value of PMV at 09.00 a.m. to 15.00 p.m. value of PMV in range of hot. Whereas, the condition of warm was found from 16.00 p.m. to 17.00 p.m. The neutral condition is at 18.00 p.m. to 19.00 p.m. This is because the room dog hotel from morning until noon

receives the most solar radiation. Air conditioning in the morning does not work well because it is still lost with solar radiation but late afternoon until evening temperatures begin to decline.
The summary of the thermal comfort prediction is indicated in the chart below:

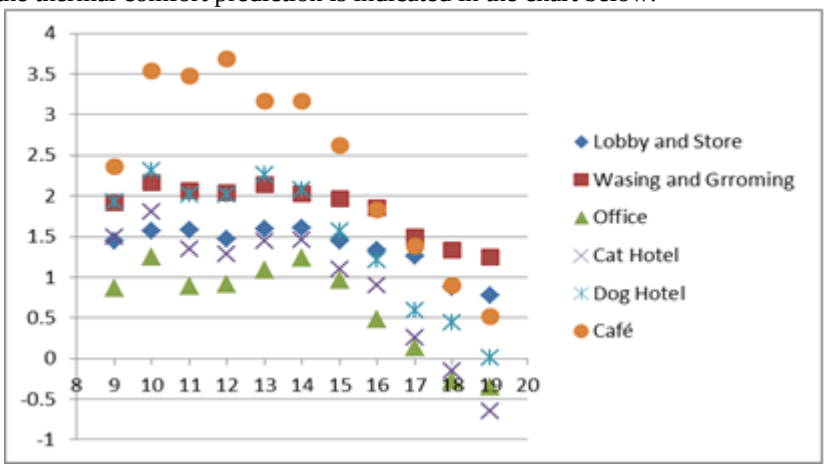


Figure 15 The thermal comfort prediction of first and second floor

Legend:

4	Very hot	2	Warm	0	Neutral	-2	Cool
3	Hot	1	Slightly Warm	-1	Slightly Cool	-3	Cold

From the chart above, it can be concluded that generally the thermal comfort of the rooms, whether in the first or second floor are above the comfort. Café has the high temperature compared to the other room mainly from 10 am to 15 pm. The other rooms, such as washing, office and cat as well as dog hotel have slower temperature than café. The rooms that achieved neutral are cat and dog hotel as well as office from 17.00 pm to 19.00 pm.

5. Conclusions

4.1. First floor

Lobby spaces, store, and toilet temperature was still within comfortable limits unless at any time during the day when the air temperature reaches 29^{0}C. while the highest air humidity in the room has reached 71.5% which occurred in the afternoon. While based on the calculation of the PMV show hot thermal conditions (+1.47) occur at any time during the day, but in the morning and evening warm thermal conditions (+0.67 to +0.34).

Washing and grooming room temperature in the morning until noon are uncomfortable whereas the air temperature reaches 30^{0}C, but in the afternoon the air temperature in the cozy confines 28,5^{0}C. The room air humidity is also relatively high at 72% occurred in the morning and afternoon. While based on the calculation of the PMV show in the morning until late afternoon heat thermal conditions (+1.85 to +2.14), in the afternoon until the evening warm thermal conditions (+1.25 to +1.49). The average temperature of the room air is not comfortable for cats and dogs while the temperature is comfortable according to the AVMA (2008) to cats and dogs in the range ^{0}C 15.5 - 26.6 ^{0}C.

The room is not comfortable for the body of cats and dogs in which the air temperature above the standard recommended by the (AVMA, 1993). Where the recommended air temperature was 15.5 ^{0}C - 26.6 ^{0}C, and the recommended air humidity is 30% - 70%.

4.2 Second Floor 2

Office space in the morning until the evening the air temperature comfortable where temperatures in the range of 23^{0}C - 28^{0}C. the humidity in the morning till night in the range of 50.5% - 64.5%. According to the calculation of PMV in the morning until late afternoon warm thermal conditions (+0.86 to +1.25) in the late afternoon to evening neutral thermal conditions (+0.13 to -0.28).

Cat Hotel room less comfortable temperatures occur in the morning until noon the air temperature is less comfortable in the temperature range 28,5^{0}C - 29,5^{0}C, at the time of the afternoon until night temperatures can be said to be comfortable where temperatures 23,5^{0}C - 28^{0}C. PMV according to the calculations in the

morning until noon heat thermal conditions (+1.84 to +1.5) while the afternoon warm thermal conditions (+0.9 to +1.46), cold thermal conditions occur at night day (0.65).

According to the AVMA temperatures acceptable for the body of cats and dogs occurred in the afternoon until the evening ^{0}C in the range of 23.5 - 25.5 ^{0}C. While the humidity in the room is still comfortable for cats and dogs.

Dog Hotel room less comfortable temperatures occur in the morning until late afternoon when the air reaches a temperature range 28,5^{0}C - 30,5^{0}C, while in the afternoon until the evening comfortable air temperature in the range 24,5^{0}C - 27,5^{0}C. According to the calculation of PMV in the morning until noon heat thermal conditions (+1.57 to +2.33), while in the afternoon thermal conditions (+0.59 to +1.21) and at night time thermal neutral conditions (+ 0.01 to +0.44). Temperatures can be accepted by the body of cats and dogs occur in the afternoon until evening in the range 24,5^{0}C - 26,5^{0}C, while the air humidity is still comfortable for the cat and the dog.

Cafe space less comfortable air temperature in the morning until late afternoon when the air temperature in the range 29,5^{0}C - 36^{0}C and in the afternoon until night temperatures begin cozy 24,5^0 - 28^{0}C. PMV according to the calculations in the morning until late afternoon heat and hot thermal conditions once (+2.36 to +3.68), while indigo PMV in the afternoon (+0.51 to +1.38).

Corridor air temperature in the morning until late afternoon less comfortable where temperatures in the range 29^{0}C - 32,5^{0}C, while air temperature in the afternoon until evening in the cozy confines where temperatures in the range 26^0 - 28^0 C. According to the calculation of PMV in the morning until late afternoon heat and hot thermal conditions once (+1.45 to +2.55), while in the afternoon until the evening warm thermal conditions (+0.71 to +0.99).

If the conclusion container buildings there are many shortcomings and uneven thermal conditions of space could be seen on the first floor and the second floor where there are differences in air temperature, humidity, and surface temperature. In the planning container buildings did not take into account climatic factors, besides the influence of the material used can also influence the thermal conditions, thus ignoring the thermal comfort.

In general, commercial facilities for pet salon using containers is less convenient from human and animal aspect. It is indicated in the lobby and store at the ground floor perceived warm sensation where the temperature reaches 29^0 C and the humidity reaches 71.5%. The room of washing and grooming also get 30^0 C. Likewise, the thermal conditions of the second floor are similar. The temperature of the office from morning to afternoon is sensed warm, that is from 23^{0}C - 28^{0}C and humidity ranging from 50.5% - 64.5%. The environment of dog hotel is hot and temperature gets to 30.5^{0}C and cat 28.5^{0}C hotel – 29.5^0 air temperature can be in accepted by the body cats and dogs occurred in the afternoon until the evening on the range 24.5^{0}C – 26.5^{0}C. The room is not comfortable for the body of cats and dogs in which the air temperature above the standard recommended by the American Veterinary Medical Association (AVMA, 1993). Where the air temperature is recommended 15.5^{0}C – 26.6 ^{0}C, and the recommended air humidity is 30% - 70%.

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Biography / Biographies (Optional)

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