

Study on Durability of Waterproofing Membrane Polyvinyl Chloride for Flat Roof

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Abstract: A house is a human dwelling that has walls and a roof that can withstand wind, heat, cold, and rain. The choice of roof for a building plays a role in terms of tidiness and comfort. In Malaysia, the selection of flat roofs is often used because it makes a residence look modern and majestic. Therefore, the problems that occur if the quality of leaks, weaknesses in the connection, and reduction of the use of waterproofing materials on the roof. So, the risk that will occur if the cause is not emphasized is that the moldy roof, ceiling, and water will absorb the building elements. The objective of this study is to examine the level of knowledge on the use of Polyvinyl Chloride (PVC) membrane on the roof of the building and to examine the level of thermal comfort of buildings using flat roofs in Malaysia. The scope of the study is divided into two, namely the questionnaire on the level of knowledge about the waterproof layer on the roof of the building and make a virtual study on the level of thermal comfort of the building for homes that use flat roofs. The data obtained from this study are respondents from students of the Faculty of Engineering Technology about the level of knowledge about the waterproof layer of PVC membrane is very encouraging and it is a very effective technique in keeping the house dry and preventing leakage. Finally, every housing should apply this technique in roof construction on these factors because Malaysia is close to the equator where weather and climate changes are sometimes rainy and hot.

Keywords: Flat Roof, Waterproofing Membrane PV

1. Introduction

A roof is a flat or steep structure built to protect a building. Roof structures are constructed of steel, concrete, or wood to support self-load, roof covering loads, and wind loads. The roof that is built should meet the needs and functions such as stability, durability, strength, weather resistance, fire resistance, thermal insulation properties, and the appearance of the building itself [1]. In construction, each building structure must take into account its safety aspects. This is because this aspect of safety is the main thing to ensure the lifespan of a building is stronger and the occupants who live in the building will be safer.

Therefore, the roof is an important thing to ensure the building and occupants are in a safe condition. However, the structure of the building has its own disadvantages. Therefore, a moisture-proof layer is created to control damage to the roof of the building [2].

Waterproofing is a combination of materials used to prevent water leakage into the structural elements of buildings and spaces in buildings. Waterproof membranes consist of waterproofing materials, rubber, or coated fabric. These materials are used in construction systems to prevent water from entering the foundation, roof, walls, basements, buildings, and structures when properly installed [3].

Membranes usually have frames made of polyester or pieces of reinforced glass such as fiberglass. For protection against ultraviolet radiation, one of the membrane surfaces is covered with small slate fragments in various colors, similar to the details. Thus, many membranes known in the field of art for structural or surface waterproofing involve the release of a component such as a sheet that does not stick to one side of the impenetrable layer before being added to the surface [4]

1.1 Problem Statement

In the present era, architects are more likely to build buildings based on modern-day concepts to make it an attraction to home selection. A flat roof is a roof with a slope of less than 10° . This flat roof frame consists of wood, iron, concrete beams, or concrete slabs [5].

Among the problems that will arise if the quality of leaks where the contractor does not ensure that the roof is in a slightly steep condition or flatten the surface. The second problem is the weakness of the connection part. Next, the third problem is that the use of waterproofing materials is not used to prevent water absorption. The cause of these three problems, the occupants of the house will suffer damage such as moldy ceilings and roofs, water will seep into other building elements and lastly, the water that flows frequently will cause leakage in the area under the flat roof if it rains heavily [6].

1.2 Project Objective

The specific objectives of this project include:

- Assess the level of knowledge on the use of waterproofing membrane Polyvinyl Chloride (PVC) on building roofs.
- Study the level of thermal comfort of buildings using flat roofs in Malaysia.

1.3 Project Scope

The scope used to conduct this study is divided into two:

- Questionnaire on the level of knowledge of waterproof membrane of PVC on the roof of buildings.
- Study of the thermal comfort level of buildings for homes using flat type roofs.

The description for the scope of this study is this questionnaire was conducted to find out the respondents' response to the waterproof layer used on the roof of the building. Respondents are students of the Faculty of Engineering Technology at Universiti Tun Hussein Onn Malaysia (UTHM) Kampus Pagoh, as well as information, is taken into account in terms of gender, age, and course. This study was conducted virtually on the level of thermal comfort of buildings for homes using flat roofs. This study was made to find out the appropriate temperature according to climate and human temperature. Therefore, the method conducted in this study is a survey of previous studies.

2. Methodology

The methodology is a key aspect during the implementation of the study such as data collection on ongoing research. The methodology also contains reports and descriptions to show evidence that can support a conclusion. This methodology has a flow chart that is used as a project research guide that has been set out in Figure 1. The first phase begins with selecting the title of the study, identifying the problem, the study's objectives and continuing the literature review. Subsequently, the second phase begins with includes pilot studies and data collection which has two parts namely questionnaires and literature review. Then, the part of questionnaires is a platform that will be answered by 50 respondents from students of the Faculty of Engineering Technology, and the literature review's part is information obtained from online sources such as websites and journals. Next, the third phase is about the analysis and discussion of this project. Finally, the fourth phase is the conclusion of the overall study in this project.

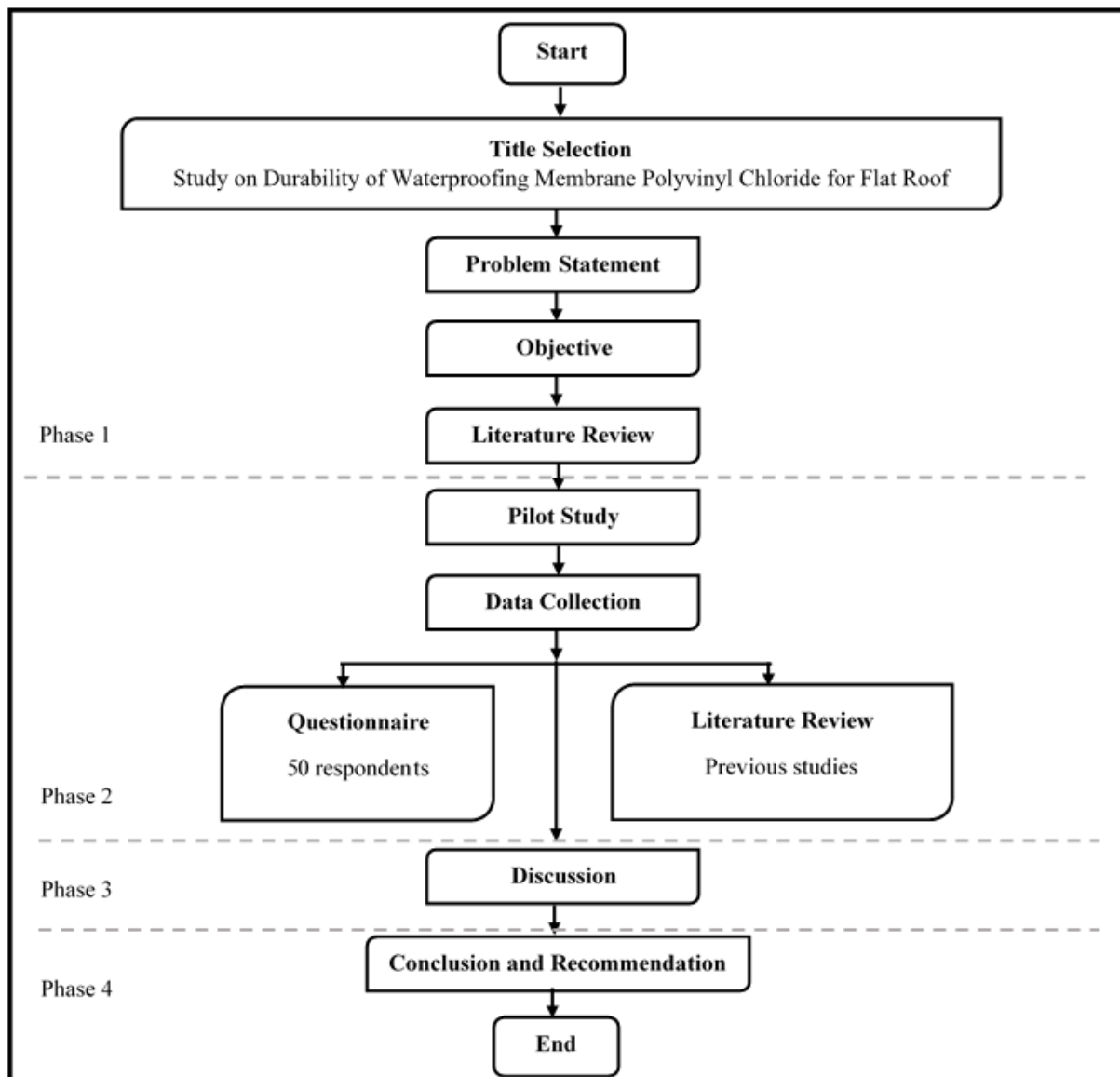


Figure 1: Methodology chart

2.1 Materials

In this study, the research tool used was the research questionnaire to determine the level of knowledge of the waterproof membrane of PVC on the roof of buildings. The questionnaire had to be

done online because of the Covid-19 pandemic and the Movement Control Order in Malaysia, and the sample size was less than it was supposed to be. The questions are created via Google Form and distributed by WhatsApp. The survey consists of four sections:

- i. Part A: Demographics
- ii. Part B: Knowledge of Waterproofing
- iii. Part C: Knowledge of Membrane Waterproofing layer of PVC on Flat Roof
- iv. Part D: Ideas and Recommendation



Figure 2: Google Form for questionnaire

3. Results and Discussion

The data analysis process is very important in the study. Qualitative research is a collection study, and the principles of qualitative data management to assist in conducting research for the study conducted. Qualitative research can help researchers access the thinking and understanding of the study subject, which can facilitate the interpretation of this research.

3.1 Survey and Data Analysis

3.1.1 Questionnaire

To achieve the first objectives, the platform of Google Form was created so that will be answered by 50 respondents from students of the Faculty of Engineering Technology. This questionnaire describes the level of knowledge about the membrane waterproof layer of PVC for a flat roof. The target respondents were 60 people consisting of students in the Faculty of Engineering Technology. Then, in this study, the number of respondents is 51 people according to the calculation from the previous researcher which determines the sample size for a specific population [7].

Part A: Demographics

Table 1 summaries the demographic percentages of respondents in Section A of this report

Table 1: Summary respondents demographics

Gender	Male	37.30%
	Female	62.70%
Age	21-23	54.90%
	24-26	42.10%
	27 & above	2.00%
Region	Melayu	98.00%
	Melanau	2.00%
Years of study	1	3.90%
	2	5.90%
	3	17.60%
	4	72.50%
Residence	Bungalow	19.60%
	Terrace	54.90%
	Flat/condominium	3.90%
	Village house (traditional)	21.60%

As shown in Table 1, the total number of respondents for women is 32 people or a percentage of 62.70 %, while the rest are respondents for the male gender which is 19 people or have a percentage of 37.30 %. Next, the total age distribution for the respondents, the highest age distribution represents the age of 21 to 23 years which has a number of 28 people or a percentage of 54.90 %. In addition, 22 respondents from the age of 24 to 26 years or have a percentage of 42.10 %, and the percentage of 2.00 % is a respondent aged 27 years and above. From this analysis, most respondents are 21 to 23 years old. In addition, the number of two types of 50 respondents were Malays or the percentage of 98.0 % and 2.0% is the percentage of the respondents who Melanau. The total year distribution for the current respondents at UTHM Pagoh Campus, Year 4 is the highest number representing 37 people or a percentage of 72.50 %. In addition, 9 people are respondents from Year 3 or a percentage of 17.60 % while Year 2 has a percentage of 5.90 % or 3 respondents, and Year 1 is the lowest number of 2 respondents and a percentage of 3.90 %. From this analysis, most respondents are Year 4 students. Finally, the type of residence occupied by the respondents. There are four types of residences inhabited by the respondents, namely bungalows, terraces, flats or condominiums, and (traditional) village houses. The highest number of residences occupied by respondents is terrace houses with a percentage of 54.90 % or a total of 28 respondents. In addition, a total of 11 respondents occupied the village house or a percentage of 21.60 %, while the bungalow house has a percentage of 19.60 % or includes 10 respondents and finally 2 respondents occupied a flat or condominium or a percentage of 3.90 %. From this analysis, most respondents live in terrace-type dwellings.

Part B: Knowledge of Waterproofing

Table 2: Summary of respondents on the knowledge of waterproofing

Questions		Yes	No
Did you know the roof has a Waterproofing Layer?		90.20%	9.80%
Do you know what waterproofing means?		96.10%	3.90%
Does your home use a Waterproofing Layer?		80.40%	19.60%

Questions	What are the advantages of using a Waterproofing Layer?			
Answer	High flexibility value	Resist at temperatures between -35 C to +85	High impact strength	The value of a real estate can be increased
	56.90%	23.50%	11.80%	7.90%

Table 2 shows the respondents' knowledge of the moisture-resistant coating in general. Most respondents are aware of the existence of this moisture-proof coating in the industry. The number of respondents who know the existence of this is a total of 46 respondents or have a percentage of 90.20 % while the rest do not know about the existence of a damp-proof layer that has a percentage of 9.80 % or 5 respondents. Furthermore, most respondents know about the meaning of waterproof which represents 49 respondents or a percentage of 96.10 % while 2 respondents do not know the definition of waterproof or the percentage obtained of 3.90 %. In addition, most respondents use a damp layer in their homes which represents a total of 41 respondents or 80.40 % while 19.60 % is the percentage of 10 respondents who do not use a damp layer in their homes. Finally, there are four advantages to using a damp-proof coating on the structure of a house or building. The highest amount of moisture-proof coating advantage is the high flexibility value with a percentage value of 56.90 % or 29 respondents. Next, 12 respondents or 23.50 % percentage obtained endurance value at temperatures between 35C to 85C while high impact strength obtained a percentage of 11.80 % or 6 respondents. Finally, the value of a real estate can be increased to get 4 respondents or 7.90 %.

Part C: Knowledge of Membrane Waterproofing layer of PVC on Flat Roof

This section is Part C which tests the level of respondents' knowledge of the waterproof layer of PVC membranes used on flat roofs. Values obtained by scale based on the value of 1 for the minimum value and the maximum value of 5, the five answers below are provided to find out which factors influence the level of knowledge about the waterproofing layer based on Table 3.

Table 3: The value obtained by scale

Scale	Frequency
1	Strongly disagree
2	Disagree
3	Satisfactory
4	Agree
5	Strongly agree

Table 4: The summaries knowledge of PVC membrane waterproof layer on flat roof

No	Questions	Frequency				
		1	2	3	4	5
1	Do you know about PVC Membrane Waterproof Coating?	1	6	13	24	7
		2.00%	11.80%	25.50%	47.10%	13.70%
2	Did you know that PVC Membrane Waterproof Layer is a layer of waterproof material placed on the surface that uses polymer material to prevent leakage?	0	3	12	26	10
		0%	5.90%	23.50%	51.00%	19.60%
3	This PVC Membrane Waterproof Layer can accommodate ultraviolet resistance.	2	1	15	26	7
		3.90%	2.00%	29.40%	51%	13.70%
4	This PVC Membrane Waterproof Layer has a high tensile strength value.	1	1	11	21	17
		2.00%	2.00%	21.60%	41.20%	33.30%
5	The resistance value of this PVC Membrane Waterproof Layer is very effective.	0	1	9	27	14
		0%	2.00%	17.60%	52.90%	27.50%
6	If this PVC Membrane Waterproofing Layer is not used on flat roofs, the risk is that the building structure will be exposed to mold spores.	0	0	6	24	21
		0%	0%	11.80%	47.10%	41.20%
7	Polyvinyl Chloride resin is a material contained in the PVC Membrane Waterproofing Layer.	0	0	11	24	16
		0%	0%	21.60%	47.10%	31.40%
8	The durability period for this PVC Membrane Waterproof Coating is for 10 years and above.	0	3	15	23	10
		0%	5.90%	29.40%	45.10%	19.60%
9	This waterproof layer of PVC membrane can provide protection for the roof of the building from leakage and damage.	0	1	6	25	19
		0%	2.00%	11.80%	49%	37.30%

Table 4 shows the distribution values for respondents' knowledge of the PVC membrane waterproofing layer. The average value of this knowledge is 3.5882 for the first question. Next, the second question refers to what most respondents know about the definition as well as the materials used for the waterproof coating of PVC membranes. Therefore, the average value for this question is 3.8431. Then, questions three, four, five, and six are the advantages of PVC membrane waterproof coating that can protect the roof from damage. The average value for the third question is 3.6862, the average for the fourth question is 4.0196, the average for the fifth question is 4.0588, and 4.2941 is the average value for the sixth question. Furthermore, the number of respondents who know PVC resin is a material contained in the waterproof layer of PVC membrane. The average value of this knowledge is 4.0980. So, the average value for the durability of this PVC membrane waterproof layer is 3.7843. Finally, most respondents agreed with the strength of this waterproof layer by obtaining an average value of 4.2157.

Part D: Ideas and Recommendation

This section requires ideas and views from respondents about the waterproof coating of PVC membranes used on flat roofs. Among the techniques used are membrane techniques, spray techniques, and paint techniques. Figure 3 shows the respondents' choice of techniques used on flat roofs. The membrane technique represented a total of 36 respondents while the painting technique was a total of 10 respondents and 5 respondents have chosen the spray technique for the selection of suitable techniques applied on flat roofs.

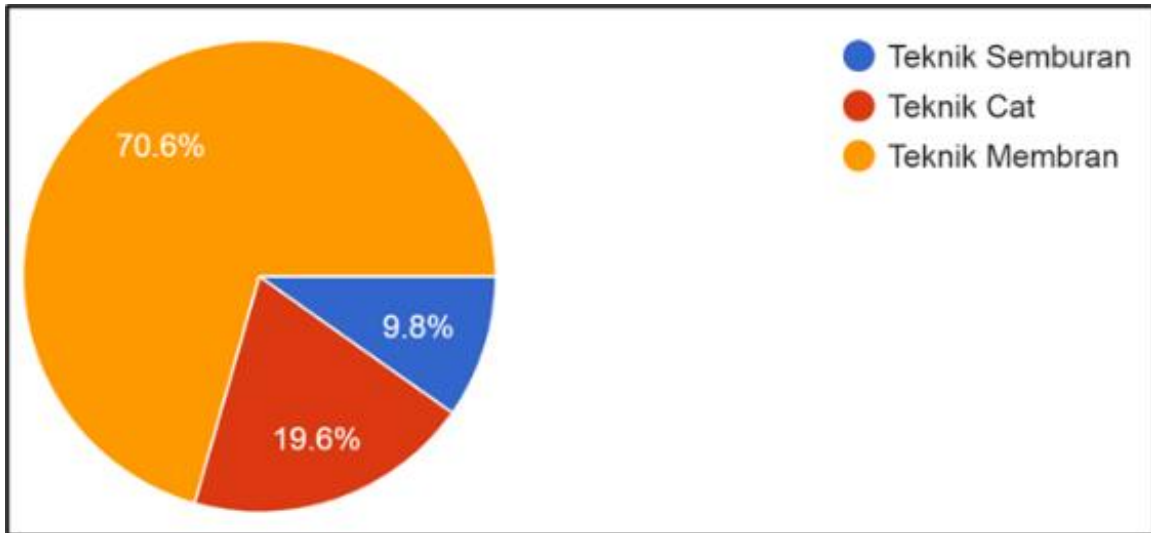


Figure 3: The respondent's choice of techniques used on flat roofs

Next, the respondents' knowledge of the PVC membrane waterproofing method used on flat roofs in Malaysia. Therefore, there are four types of methods that describe how respondents know it. Among them are through books, through the internet, through contractors, and through friends in Figure 4.

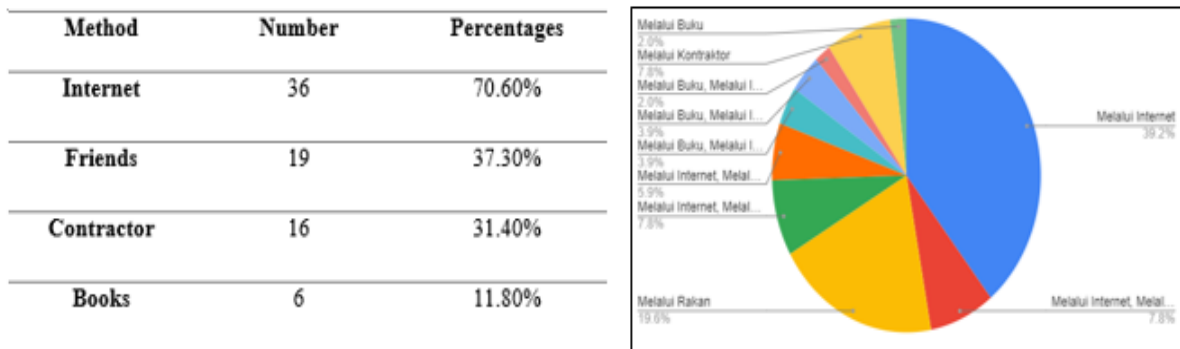


Figure 4: Amount and percentage to represent each method implemented

Figure 6 shows the importance of installing a waterproof layer of PVC membrane for flat roofs. A total of 48 respondents or 94.10 % stated that they agreed while a percentage of 5.90 % or 3 respondents did not agree on the importance of installing a waterproof layer of PVC membrane.

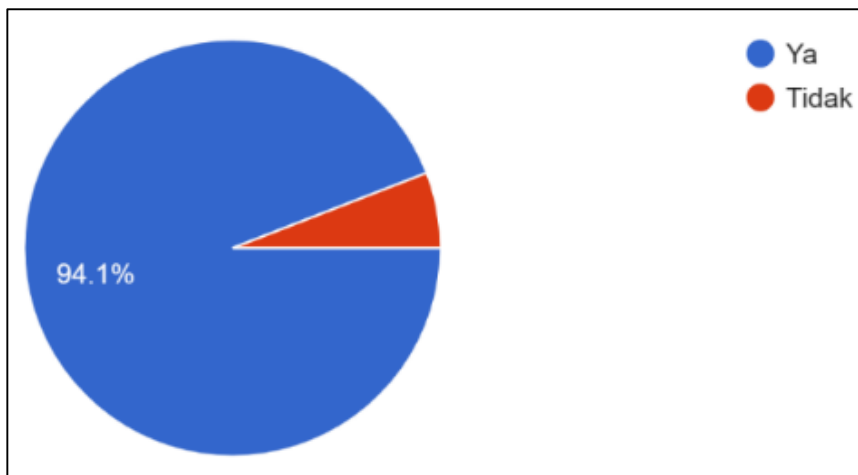


Figure 6: The importance of installing a waterproof layer of PVC membrane for flat roofs

Lastly, additional cost for the installation of waterproof coating of PVC membranes on each housing especially the use of flat roofs. Figure 7 shows the number and percentage of respondents who agreed with the increase in costs. The number of respondents who agreed was 48 or 94.10 % while 5.90 % or 3 respondents did not agree to the additional cost for the installation of PVC membrane waterproofing.

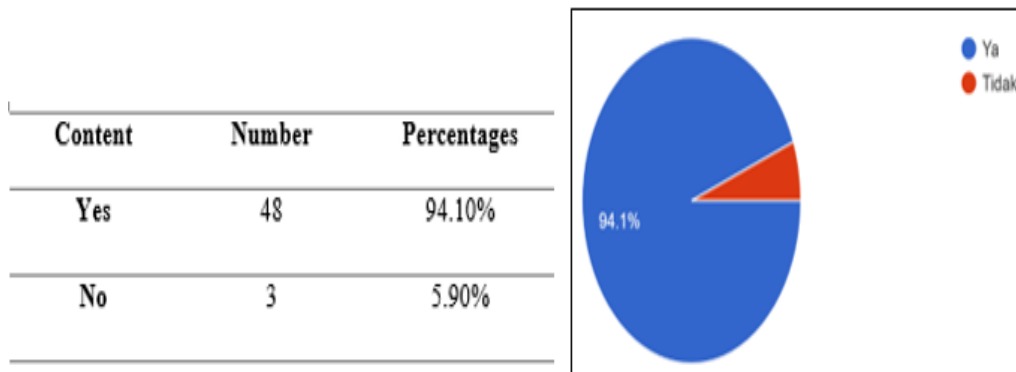


Figure 7: The number and percentage of respondents who agreed with the increase in costs

3.1.2 Previous Research

To achieve the second objective which is to study the level of thermal comfort of buildings for residential use using flat roofs used in Malaysia. These studies have been researched by examining several journals from previous researchers on the topics conducted. Therefore, there are two researchers who have studied the thermal of buildings in Malaysia. The description of the study in Table 5.

Table 5: Summaries from previous researchers on the topics conducted

No	Tittle and Author	Contents	Figure
1	The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot-humid climate (2016) (Mirrahimi et al., 2016, p. 1512) [8]	The authors of this study investigated the effect of building envelopes on energy consumption and thermal efficiency in the tropical environment of high-rise buildings in Malaysia. Due to the comfort of the occupants of the building, the acceptable thermal condition of the interior of the building is important. Recent research conducted in Malaysia shows that residential buildings comprise about 19% of Malaysia's total energy consumption. The passive design approach is one of the most effective techniques for building envelopes in hot humid tropics and is done in hot humid tropics to make envelopes. This paper covers the findings of another study evaluating the selection of high-rise residential envelope parameters of the building. In Malaysia, continuous exposure to solar radiation to the surface of a building causes an increase in the amount of energy required for cooling purposes. This surface must	<p>High and low temperature values</p> <p>Wind speed - mildest wind from Northwest (17%), North (14%), South (12%) and West (11%).</p>

be protected to reduce heat inflow, directly or indirectly. All strategies to prevent construction from sunlight can be incorporated into heat avoidance techniques. Shades that are particularly suitable for openings, building orientation, plants around the building, and materials suitable for facades are some smart strategies for providing a comfortable indoor temperature.

This strategy can be applied in different climates and is recommended for tropical climates where high amounts of solar radiation are unavoidable.

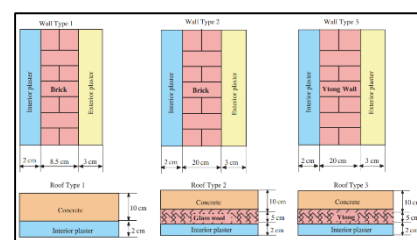
It is designed to protect the building while providing thermal comfort from adverse environmental conditions. In addition to releasing thermal comfort, using poorly constructed building envelopes can lead to higher usage. In short, the construction of a construction envelope affects energy consumption. By protecting the interior from direct sunlight penetration, thus reducing glare, minimizing water penetration, providing natural ventilation, reducing external reflections, providing views, and serving as a thermal barrier, building envelopes minimize energy consumption.

Researchers	Neutrality value/ Tn C	Indoor design condition		
		Comfort range (°C)	RH%	Air velocity (m/s)
[24]	30 °C regardless of the adopted methods	N/A	N/A	N/A
[25,26]	26.4 °C	Between 25.3 °C and 28.2 °C by 90% satisfaction	N/A	N/A
[27]	28.2 °C	25.0-31.4 °C	45-90%	N/A
[28,29,30]	26.2 °C for both mixed mode and air-conditioned buildings, and 25.5 °C for the climate controlled buildings	N/A	50% RH and no air movement	N/A

Thermal comfort study conducted in Malaysia

No	Title and Author	Contents
2	Estimation of total equivalent temperature difference values for multilayer walls and flat roofs by using periodic solution (2007) (Yumrutaş et al., 2007, p. 1881) [9]	According to this study, the authors investigated the value of equivalent temperature difference (TETD) based on time delay and decrease factor estimated using hourly solar radiation measured on the horizontal surface and outside air temperature. Time pauses and reduction factors are obtained numerically using periodic solutions to the problem of temporary one-dimensional heat transfer for building structures. The solution is used to find the temperature variation inside the structure every hour, the increase in heat to the building through the structure, the highest and lowest temperatures on the inner and outer surfaces of the roof and walls, and the time required to reach this temperature.

Figure



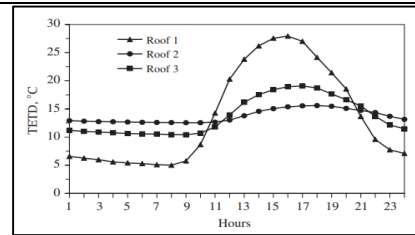
Schematic representation of roof and wall types used in this study.

Material	Density (kg/m ³)	Thermal conductivity (W/mK)	Thermal diffusivity (m ² /sec)	Specific heat (J/kgK)
Plaster	2778	0.7	3×10^{-7}	840
Brick	1580	0.69	5.2×10^{-7}	840
Ytong	1580	0.15	5.2×10^{-7}	840
Glass wool	24	0.038	22.6×10^{-7}	700
Concrete	2076	1.37	7.5×10^{-7}	880

Thermophysical properties of roof and wall materials

Their study shows that as a result of the increase in thermal power, the temperature of the inner surface of the wall reaches a fixed value at which the thickness and thermal conductivity remain constant. The authors found that the thickness of the material and the shape of the material have a very profound effect on time pauses and decrease factors. One of the reliable, but realistic cooling load calculation methods is the TETD method which uses time interval and decreases factor.

As a function of air temperature and sunlight flux, the temperature distribution in the wall should be found. To achieve this temperature distribution, temporary heat transfer problems need to be solved. Heat transfer from the roof of a building or wall structure to space can be represented as a function of the interior wall surface and room temperature, and the thermophysical characteristics of the structure.



Influence of roof thermophysical properties on TETD values

4. Conclusion

The overall summary of the study shows that the study has met the objective of the study which is to study the level of knowledge on the use of damp-proof coating on flat roofs and study the level of thermal comfort of buildings using flat roofs.

The results of the overall analysis found that the level of knowledge of the respondents about the waterproof layer of the PVC membrane is very good because every questionnaire was given, the respondents have given accurate and good answers. At the same time, this questionnaire provides exposure to respondents and suggestions regarding the waterproof layer of this PVC membrane. This outcome from Section 2 in the questionnaire. The percentage of respondents who know that roof has a waterproofing layer is 90.20 %. Thus, for Section 3 are the percentage and average values are 47.10% and 3.5882 for respondents who know about PVC membrane waterproofing coating. In addition, waterproof coating of PVC membranes is very important in the construction procedure of a building that has a flat roof, especially to prevent damage and leakage on the roof of the house as soon as reducing the value of a building. Therefore, the industry must apply this technique in construction due to the construction of houses in Malaysia often using a flat roof which is the main choice of contractors.

Acknowledgement

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