Development of Lightning Protection System (LPS) Designing Tool

By

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16466

Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr. Mohd Fakhizan bin Romlie)

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

September 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SAMUEIL BIN IDRIS

ABSTRACT

Building structures are commonly exposed with the lightning phenomenon. Due to that, sometimes, it may cause a threat and bring an injury due to direct strike to the structure and hence may harm and gives physical damage for whomever near the risky area and this also may result to failure of internal system of the building. Therefore, a Lightning Protection System (LPS) is a system whereby it can prevent this to happen and reduce the risk to minimum. Where, Lightning Protection Systems is a system that is installed on building structures to protect it from the lightning strike being diverted. By that, it can dissipate the lightning current safely to pass a though the building structure and to the ground. Lightning Protection System consists of three major parts which are air terminal, down conductor and also grounding system. In designing this Lightning Protection System tool, it was followed based on the updated standard which is NFPA 780-2014 and was focused on three roof types which were ridge, flat and pitched roofs. Based on this standard, the data and mathematical equations were obtained to form algorithms whereby it would be used in the software afterwards. The tool would be developed and conducted by using Microsoft Excel 2010 since the algorithm was fit to be formulated in this software. Just then, the input and output interface should be constructed and thereby, by selecting and key an option provided, a user could have some basic idea on how the designing of Lightning Protection System work done and hence, show the criteria to design the Lightning Protection Systems.

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LIST OF ABBREVIATION

NFPA = National Fire Protection Associates

LPS = Lightning Protection Systems

IEC = International Electro-Technical Commission

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is one of the countries amongst all the countries in South East Asia where the lightning activities were happened gradually especially when it comes to the end of year. Lightning strike phenomenon can be in the range of 3kA until 300kA when it is occurred. Prior to that, it may hit and affect the structure of the building at anywhere and anytime particularly if there is no such thing as protection system. Therefore, Lightning Protection System needs to install in avoiding unnecessary event that may occur.

The objective of Lightning Protection System (LPS) is to optimize in catching the hits of the lightning strike and then, carry the heavy lightning current safely through the building by down conductor and discharge it to the ground. In detail, it consists of three major parts which is air terminal, down conductor and also grounding system.

Air terminal is the part where the lightning will be striking at for and will carry the lightning current to channel it to down conductor. Down conductor, in other way, is the part where it will carry the lightning current that has been hitting the air terminal where the conductor will be placed in around the building before passing the current down to the grounding system. Whereas, the grounding system part will be consists of ground electrode where it is the final step of the LPS whereby the lightning current that is received from down conductor will be to the ground safely.

One of the renowned standards that had released a guideline of Lightning Protection System was namely National Fire Protection Association (NFPA) 780, Standard for the

Installation of Lightning Protection System. This standard precisely explains the proper way to install the Lightning Protection System based on the categories. Due to the frequently occurring risk, injury and physical damage annually caused of by the lightning phenomenon, therefore, this standard is regularly updated so, the Lightning Protection System designing and installation guide will become more efficient.

1.2 Problem Statement

Effects of the lightning strike to the structure may result into an unfortunate event. The undesired outcomes from the event are such as a fatal injury, mortality, a physical damage to the structure, a failure of internal systems, and etc. These all factors might be possible if the Lightning Protection Design was not properly designed and installed. Besides that, all the information from the standard need to be justified in detail before pursuing in design and installs the Lightning Protection System. Improper design will result in the unfortunate events and undesired outcomes as mentioned above. But, one thing that needs to be taken into account is that, not all people can literally understand and follow a such standard guideline. People will get it hard to read and trying to understand a standard and will find it difficult later on. Therefore, a comprehensive tool in relation to the design of the Lightning Protection System is vital to be developed so that it could be easily understood for the users to become familiar with.

1.3 Objectives

Prior to the problem statement as mentioned above, hence, a few objectives are constructed.

- To develop the Lightning Protection System designing tool that can assist and easy for user to handle with.
- To understand the risk assessment flow for lightning frequency occurrence.
- To determine the air terminals, down conductor and ground electrode specifications for such criteria needed in designing the LPS tool.

1.4 Scope of the project

In this project, it will be covered by referring an updated recognized standard which is National Fire Protection System (NFPA) 780 version 2014 where this is the most recent update of NFPA standard. Related to that, the project's scope will be just focused on three types of roof to be further analyzed which namely 'ridge' type of roof, 'flat' type of roof and lastly 'pitched' type of roof. Therefore, the design and development of LPS tool using Microsoft Excel 2010 would mainly focus on these three types of roof.

CHAPTER 2

LITERATURE REVIEW

The effectiveness regarding the use of Lightning Protection System (LPS) is currently still debatable to date, whereby there are postulates and speculations stating that the current LPS standard used is outdated and does not contain the updated and concise information required for practical use [1].

In the LPS scope, the issues rise significantly involving the air terminal and/or the lightning rod, that is to say the characteristics for the lightning rod in the Lightning Protection and Safety issues are highly challenging and remain difficult to determine for the most appropriate selection. This occurs due to the fact that the lightning phenomenon is an unpredictable natural event and the phenomenon cannot possibly be generated. This natural phenomenon also cannot be easily formed nor duplicated even with the latest modern methods such as rocket-triggered lightning [2]. The incapability for the other components such as down conductor and grounding system may still be emphasized [2]. Based on the controversial issues arising with respect to the systems involved, hence, all the trials, tests, developments, and techniques have been documented to further enhance and improve the LPS standard up to date [2].

In relation to the lightning phenomenon, thus, the unexpected yearly lightning occurrences will cause numerous accidents including the morbidity or fatality especially to humans. Moreover, with the difficulty to predict the upcoming lightning phenomenon incidence, it is hard to pose warning notices to the public users [3].

In Malaysia, researches have been conducted over these years and according to these studies, it was found that approximately 100 to 150 fatalities occurred due to the lightning incidences annually. These significantly high figures were higher compared amongst the other South East Asia countries [4].

Nonetheless, in another research study case, it was concluded that the lightning would be much prone and sensitive to the parameters such as office and household buildings in comparison to the evident effects on the physical damages. The continuation of the studies showed that the lightning phenomenon poses higher risk to affect the building structure, and the risks affecting living creatures were on the minimum levels [5].

In LPS, the important components must be taken into consideration, such as air terminal, down conductor and the earth termination system. This is to ensure every types of material chosen and used in designing LPS are capable to stimulate a better electrical conductivity, possess sufficient strength to withstand loads and lightning current's electromagnetic effects [6].

The same research study showed the risk for building structure contents including residents safety could be minimized if LPS materials are improved by selecting the right and suitable choice of materials [6]. Thus, it is evident that the designing and installation for the building structures are vital and of the high importance.

2.1 Air terminals

The function of the air terminal was to intercept the lightning which can cause damage to the structure and therefore for the building to be protected. Recent researches in Malaysia had conducted for field survey of by-pass air terminal on structure, and from that, with design criteria taken of the structure such as width, height and length, the failure distance for maximum protection requirement of the structure had been determined [7].

For pitched roof area, it was stated that lightning rod did not require eave heights which were below than 15 meters. Furthermore, for the height of the structure which exceeded 30 meters and the eaves were above 15 meters but below 46 meters, therefore, air terminal should be considered for eaves area. But contradict to the pitched roof, the flat roof should have an additional air terminal if it exceeds 15m in length and also the width of the roof and the location for the additional must be less than 15 meters of the roof area [8].

Table 1: Survey of air terminal event structures in Malaysia

No	**Building dimensions H x W x L (m)**	**Air Terminal Type**	**Air Terminal Height (m)**	**Failure distance (m)**
1	25 x 75 x 18	Vertical Rod	0.5	0. 0.1, 0.2
2	12 x 70 x 20	Vertical Rod	0.5	1.5, 2
3	30 x 72 x 20	Vertical Rod	0.5	4.2
4	30 x 75 x 100	Vertical Rod	0.5	7
5	15 x 18 x 25	Vertical Rod	0.5	6.5
6	20 x 22 x 17	Vertical Rod	0.5	4.5
7	30 x 90 x 15	Vertical Rod	0.5	1, 2, 2.2, 3
8	10 x n/a x n/a	Vertical Rod	0.5	0.2, 1.1
9	30 x 90 x 15	Vertical Rod	0.5	0.2
10	10 x n/a x n/a	Vertical Rod	0.5	All zero
11	30 x 16 x 15	Vertical Rod	0.5	0.1, 0.15
12	110 x 30 x 25	Vertical Rod	0.5	1.3, 2.3
13	40 x n/a x n/a	Vertical Rod	0.5	0.2
14	75 x 45 x 30	Vertical Rod	0.5	0.5
15	25 x 75 x 18	Vertical Rod	0.5	0.3
16	15 x 75 x 25	Vertical Rod	0.5	1.5, 2.5
17	15 x 50 x 25	Vertical Rod	0.5	0.1, 3
18	50 x 30 x 25	Vertical Rod	0.5	1.1
19	25 x 75 x 18	Vertical Rod	0.5	4
20	25 x 75 x 20	Vertical Rod	0.5	3

2.1.1 Zone of Protection

In designing the Lightning Protection System, the methods that generally discuss on selecting and placing the air terminal and down conductor are as follows:

- Mesh method
- Rolling Sphere method
- Angle method

2.1.1a Mesh Method

Mesh method was basically called Faraday Lightning Protection method. Whereby, the theory is was from the Franklin rod schemes. It was the probability of the lightning rod for structure which had been equipped with the mesh protection that will be struck by the lightning [9].

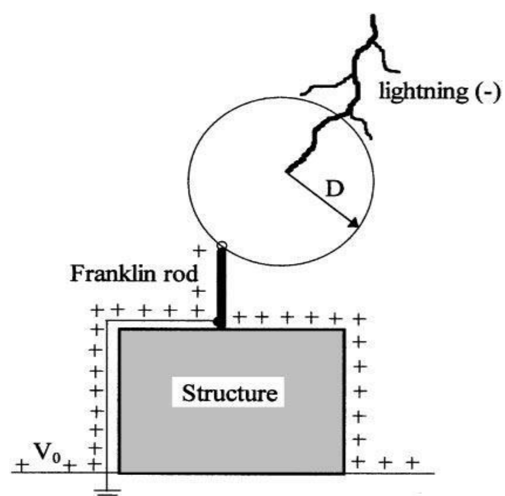

Figure 1: Lightning side strike for structure protection

Table 2: Mesh size requirement for levels protection

Protection Level	Protection effectiveness (%)	Mesh square side (m)	Mesh size (m2)
I	98	5	10 x 10
II	95	10	15 x 15
III	90	15	20 x 20
IV	80	20	25 x 25

2.1.1b Rolling Sphere Method

Rolling sphere concept was initiated to determine the possibility of the lightning side strike effect on the building structure. In this concept, the lightning protection would be needed if the sphere evaluation touches the structure. If not, therefore, the protection would not be needed [10].

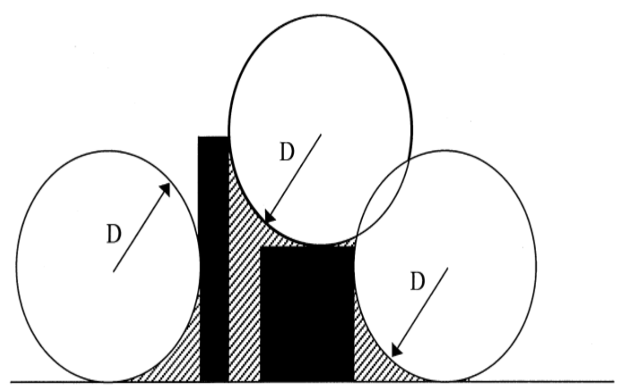

Figure 2: Rolling Sphere protection idea

Table 3: Rolling Sphere protection level

Protection Level	Protection effectiveness (%)	Rolling Sphere radius (m)
I	98	20
II	95	30
III	90	45
IV	80	60

Whereby the theory of the rolling sphere method is based on two conditions:

1. The lightning strike point would be determined if the leader approaches the structure by a distance.
2. The nearest object from the lightning strike point is the sphere center point.

2.1.1c Angle method

For multi-level-roof building structure that did not exceed 15 meters in height. Angle method was highly recommended for zone of protection. Where building with the height which did not exceed 7.6 meters should be protected by using one-to-two zone of protection and structure which did not exceed 15 meters should be protected by using one-to-one zone of protection []. The zone of protection would consider the highest peak of lightning rod from one building to another. Therefore, the calculation based on angle formula $x^2 = y^2 + z^2$ would determine the safest zone in meters for lightning rod installation exception.

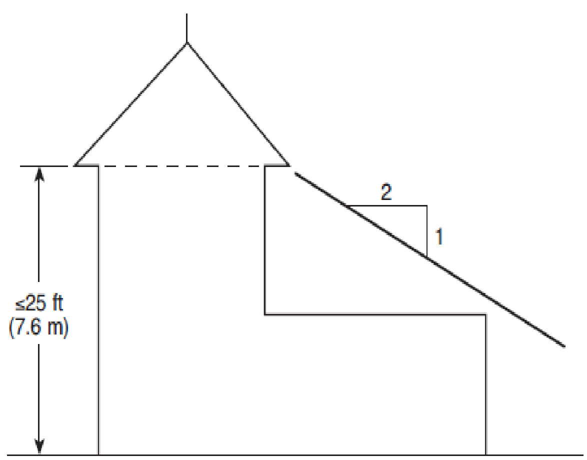

Figure 3: One-to-two zone of protection

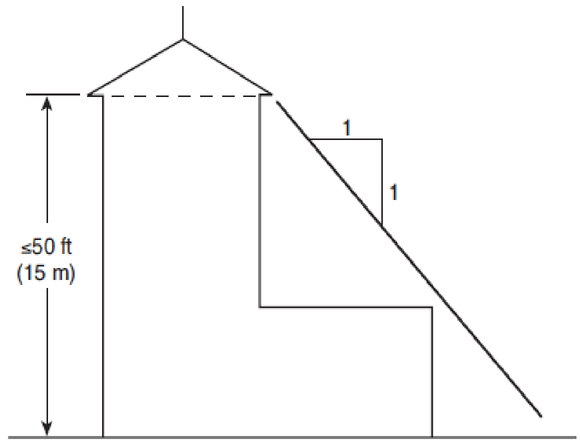

Figure 4: One-to-one zone of protection

2.2 Down conductor

The purpose of the down conductor was to be used as a connector between air terminal direct through the ground. As a connector, it would discharge the current that is coming from the lightning strike. Due to that purpose, down conductor needed to have a low reactance and resistivity for it to carry the amount of current safely flows to the ground. The selection of the conductor was based on the type of the conductor material requirements that needed to be used. Generally, it had two types which were copper and aluminium and the selection were made according the parameter [8].

Table 4: Minimum Class I material requirement

Type of conductor	**Parameter**	**Copper**	**Aluminum**
Air terminal, solid	Diameter	9.5mm	12.7mm
Air terminal tabular	Diameter Wall thickness	15.9mm 0.8mm	15.9mm 1.63mm
Main conductor, cable	Size strand Weight per length Cross-section area	1.04mm^2 278 g/m 29mm^2	2.08mm^2 141 g/m 50mm^2
Bonding conductor, cable	Size strand Cross -section area Thickness Width	1.04mm^2 13.3mm^2 1.30mm 12.7mm	2.08mm^2 20.8mm^2 1.63mm 12.7mm
Main conductor,	Thickness	1.30mm	1.63mm

solid strip	Cross-section area	$29mm^2$	$50mm^2$

Table 5: Minimum Class II materials requirement

Type of conductor	**Parameter**	**Copper**	**Aluminum**
Air terminal, solid	Diameter	12.7 mm	15.9 mm
Main conductor, cable	Size strand Weight per length Cross-section area	$1.05\ mm^2$ 558 g/m $58\ mm^2$	$2.62\ mm^2$ 283 g/m $97\ mm^2$
Bonding conductor, cable	Size strand Cross -section area Thickness Width	1.04mm2 13.2 mm2 1.30mm 12.7mm	$2.08mm^2$ $20.8\ mm^2$ 1.63mm 12.7mm
Main conductor, solid strip	Thickness Cross-section area	1.63 mm $58\ mm^2$	2.61 mm $97\ mm^2$

2.2.1 Bonding

For certain criteria, bonding application might lead to slightly reduce the lightning strike to the building structure [11]. For structures that exceeded more than 40 ft. (12m) in height. It was required to calculate the value of the bonding distance. This would be determined by the factors of vertical distance between the bonds (h) also the value of the down conductor that would be placed (n). The formula was given by:

$$D= (h \div 6n)*(Km)$$

Where K = constant flashover through wood, brick and etc. in the value of 0.5 and 1 for flashover through air.

This formula also would apply for the structures less than 40 ft. (12m) in height. While the value of ‘n’ was determined by the value of conductor that would be used. The value of this was described as below:

n= 1, for one conductor

n= 1.5, for using two conductors

n= 2.25, for exceed in using more and equal to three conductors

Besides that, this also applied for the metallic structure, reinforced concrete structure and also for the other structures. Reinforced structure required level that did not exceed 200 ft. (60m) for installing the conductors while the others structure required level height of not exceeding 60 ft. (18m) to perform intermediate conductor and ground media [12].

2.3 Grounding System

It was stated that grounding electrode must not be less than 2.4 meters long and 12.7 millimeters in diameter. Besides that, it was noted that the grounding electrode must be positioned vertically below 3 meters into the earth []. For ground ring electrode, it must be contacted at the depth of below 460 millimeters to the earth while concrete-encased electrode is just used for new building structure only and its conductor must be not exceed 6 meters for size and noted that the diameter must always be less than 12.7 meters. But, contradict with radials electrode where the length must be not less than 3.6 meters. Next, for ground plate electrode, the criteria for thickness must be a minimum of 0.8 millimeter and 0.18 mm^2 for minimum surface area [8].

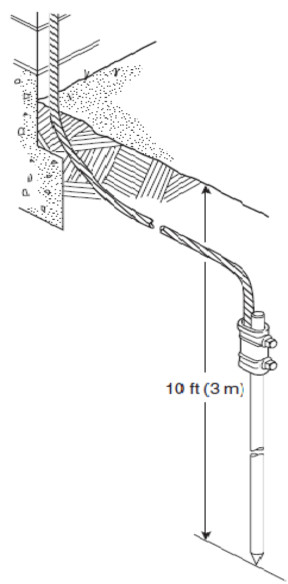

Figure 5: Installation for ground electrode

CHAPTER 3

METHODOLOGY

In this LPS, the designing tool construction was conducted by using Microsoft Excel 2010. There are four assessments that will be involved to be developed which are;

1. Risk assessment
2. Strike termination device assessment
3. Down conductor assessment
4. Grounding assessment

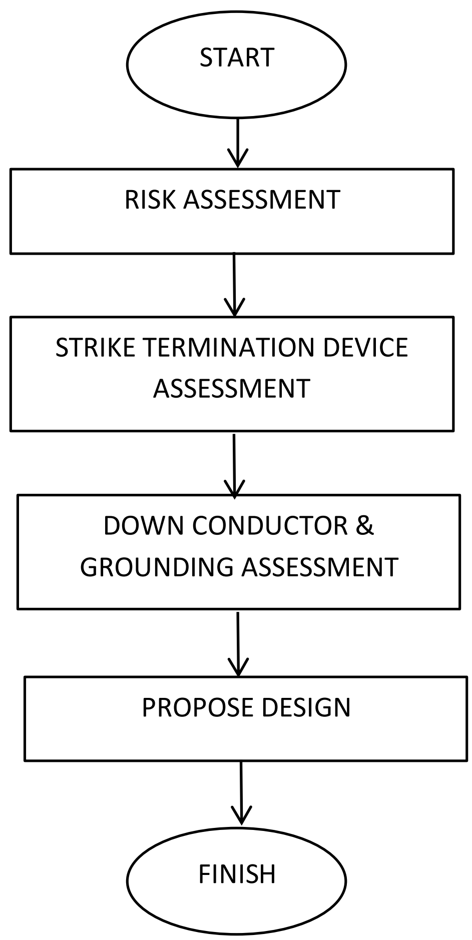

Figure 6: LPS flowchart

3.1 Risk assessment

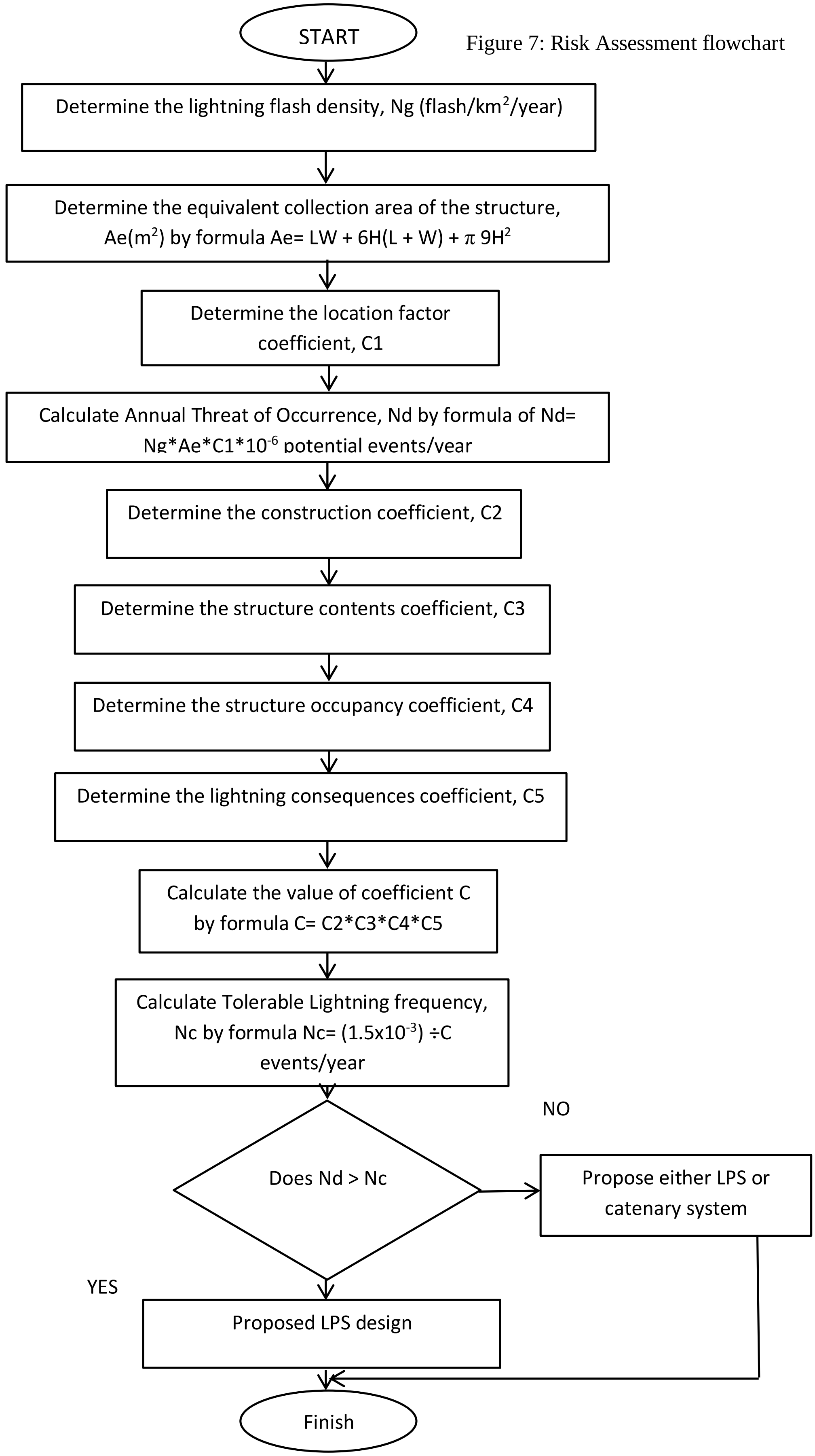

Figure 7: Risk Assessment flowchart

In general, assessment which had been conducted in this stage to define whether the value of Nd is bigger or otherwise smaller that the value of Nc. This is a very important value to be highlighted due to the fact that the factor itself will determine whether the use of LPS would be compulsory or optional.

Based on the risk assessment flow chart shown above, the tool would be constructed by evaluating the value of Nd first, following by evaluating the value of Nc). The first step in estimating the value of Nd was by determining the Lightning Flash Density, Ng (flash/km^2/year). Consequently, this value was taken based on the map provided which showed the related annual lightning density incidents in the South East Asia.

Subsequently, the assessment should be followed by determining the equivalent collection area of the structure, Ae (m^2) by using formula of Ae = LW + 6H(L+W) + $\pi 9H^2$. Then, continued by determining the Location coefficient, C1 which the value of coefficient provided are around 0.25, 0.5, 1 and 2 to be selected.

Upon completion for determination of these three perimeters which are Ng, Ae and CI respectively, therefore, the value of Nd could be determined by using formula of Nd = Ng x Ae x C1 x 10^{-6} (potential events/year).

Right after evaluating the value of Nd, it would be followed up in determining the value of Nc. The first process was by determining the construction coefficient, C2, which the value of the coefficient to be taken is based on the type of the structure and roof whether it is metal, nonmetallic or combustible, which each different type of structure and roof will be given different value of coefficient.

The next step taken wasto determine the value of structure contents coefficient, C3 which would be given a range value of coefficient starting from 0.5, 1.0, 2.0, 3.0, and 4.0 to be selected based on low, standard, moderate or high value of combustible, noncombustible and flammable content.

After determining the value of C3, the next step would be followed up by determining the structure occupancy coefficient, C4 which involved the value of coefficient of 0.5, 1.0, and 3.0 to be selected based on the occupancy level. The last coefficient to be determined was Lightning Consequence Coefficient, C5. This was when the levels of the consequences to the environment appeared and the value range of 1.0, 5.0 and 10.0 to be selected.

Eventually, the evaluating process should be continued by calculating all the values of the coefficients that had been selected by using the formula of $C = C2 \times C3 \times C4 \times C5$. Therefore, the value of Nc can be calculated by using formula of $Nc = (1.5 \times 10^{-3}) \div C$ (events/year).

Statement process would be developed to define whether the value of Nd is greater or not to the value of Nc. If Yes. Hence, LPS design is compulsory and should be proposed. But, if the answer is No. Hence, LPS design is optional to be proposed.

3.2 Strike Termination Device

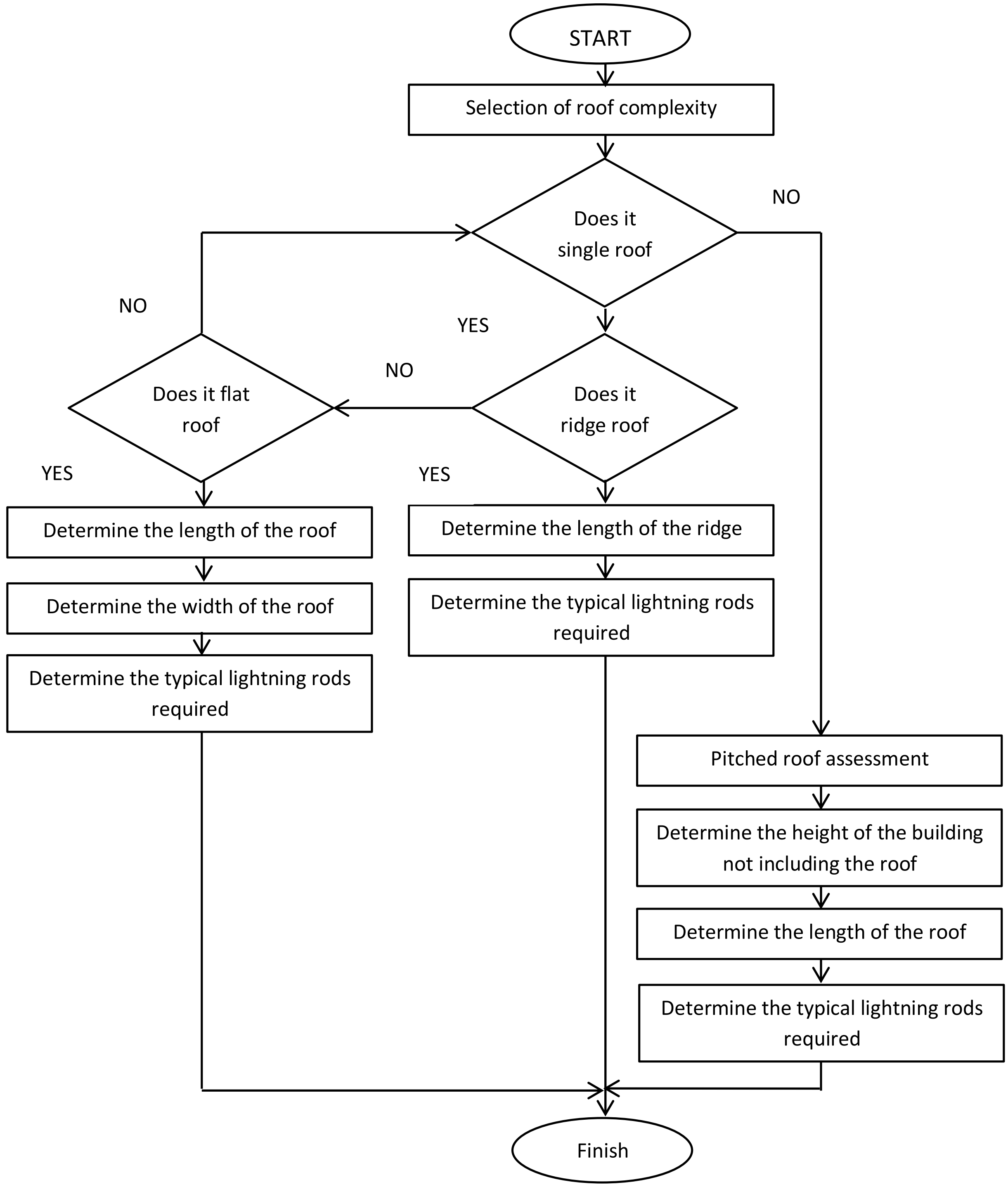

Figure 8: Strike Termination Device flowchart

In general, this assessment for this stage is to identify the amount of air terminals or lightning rods which should be placed for building structure according to the criteria. Based on by the complexity of the types of the roofs.

Assessment should be started by making a decision for selection of the roof complexity which consists of single type of roof and complex roof. Then, the next process is evaluating a decision making whether it is a single roof or not. If Yes, hence, the assessment would be carried forward. But, if No, the assessment would directly go to the complex roof part. When the answer for that is Yes just now, the assessment will carry to the next decision making which is whether is it a ridge type of roof or not. If Yes, the assessment will continue in determining the ridge part. But, if No, the assessment would directly go to the next part of single roof type which is flat type roof

For ridge type roof, the assessment should be started by determining the length in meter (represented by y) of the ridge. Then, followed with determining the typical lightning rods required by using a formula of $x = ((y-0.6) \div 6) + 1)$.

For flat type of roof, the assessment should be started by determining the length of the roof itself (represented by y). Then, followed up by determining the width of the roof (represented by w). Therefore, determination of the typical lightning rods which were required will be calculated by using a formula of $x = (((y-0.6) \div 6) + 1) + (((w-0.6) \div 6) +1)$.

For complex roof, it would include the process of assessment for pitched roof area. The process would be conducted by determining the height of the building in meter (without including the roof height). Then, the steps would be followed by determining the length of the roof (represented as y). After that, the assessment for determining the value of lightning rod needed would be carried out by using the formula of $x = (((y-0.6) \div 6) \times 3)$, which would also include the value for the eaves of the roof.

3.3 Down conductor and Grounding electrode

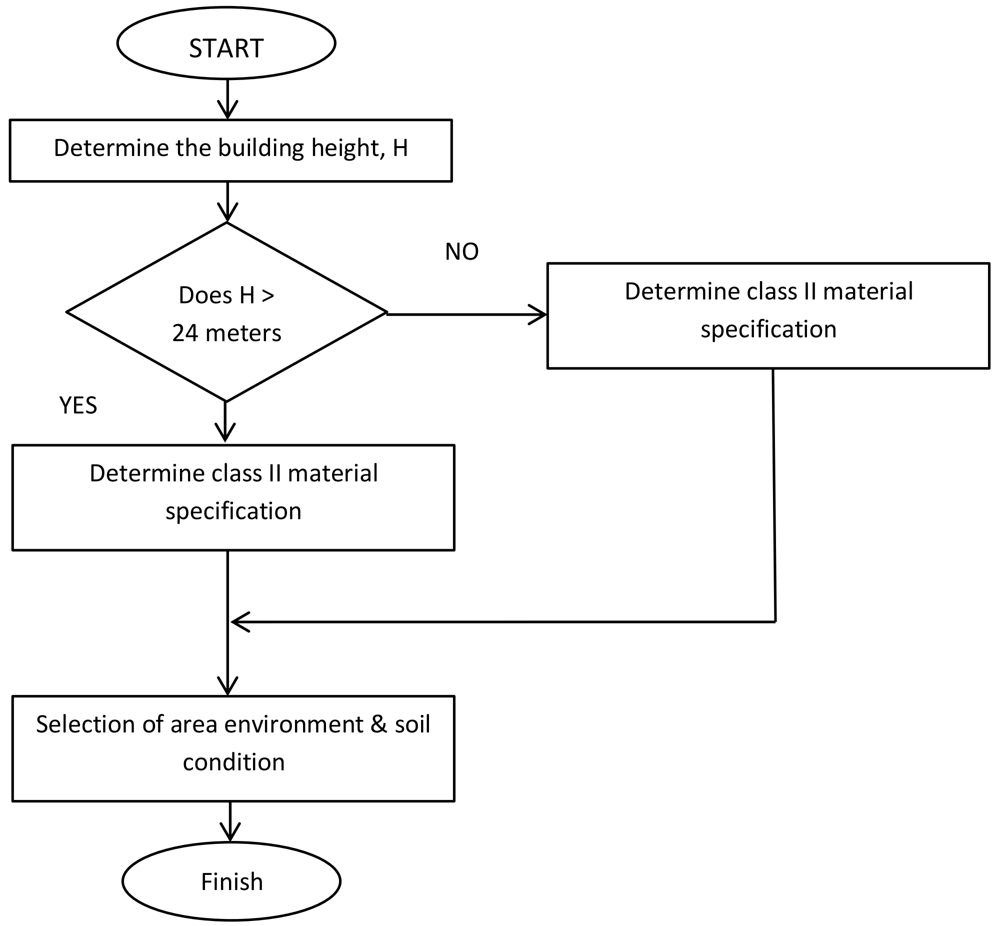

Figure 9: Down conductor & Grounding System flowchart

In general, assessment for the down conductor was constructed to find the suitable class material specification of the conductor that will be used to connect from the end of the air terminal directly to the ground electrode. Therefore, the specification of the down conductor was vital for this assessment. Meanwhile, the assessment for grounding system in general was to determine the specification of the ground electrode which is fit to be used based on the assessment condition.

For down conductor assessment, the process was started by determining the building structure height. Decision making was constructed to analyze whether the height of the building is exceeding 24 meters or not. If Yes, the process should be followed up by determining the specification of down conductor and air terminal for class II material. But, if No, therefore, the assessment will be carried forward to determine the specification of down conductor and air terminal for class I material. Furthermore, the assessment for the grounding was made by making a selection for the area environment and soil condition assessment.

3.4 Proposed Design Requirement

After completing all the assessments, the outputs from each assessment would be summarized in one constructed section. By then, at least the users would have an idea for what kind of specification and requirements such needed. By that summary, the proposed design requirement of the LPS tool would cover the number of how many air terminals or lightning rod such needed the specification of down conductor and air terminal, also, the specification of grounding electrode that would be involved.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Risk Assessment part

The objective of this part is to determine whether LPS is necessary or optional. The risk assessment was done by comparing the lightning strike frequency, Nd, to the structure and tolerable lightning frequency, Nc. If the value of lightning strikes frequency is found to be less or equal to tolerable lightning frequency; hence, LPS is optional to be installed, and if lightning strike frequency exceeds tolerable lightning frequency; therefore, LPS is compulsory to be installed for avoiding the possible risk if the lightning strikes to the building structure.

To obtain lightning strike frequency, Nd, three parameters which are lightning flash density flash density, the equivalent collection area of the structure, and environmental coefficient were determined. For tolerable lightning frequency, Nc, there are four factors involved in getting the value which are structural coefficients, structure contents, structure occupancy, and lightning consequence.

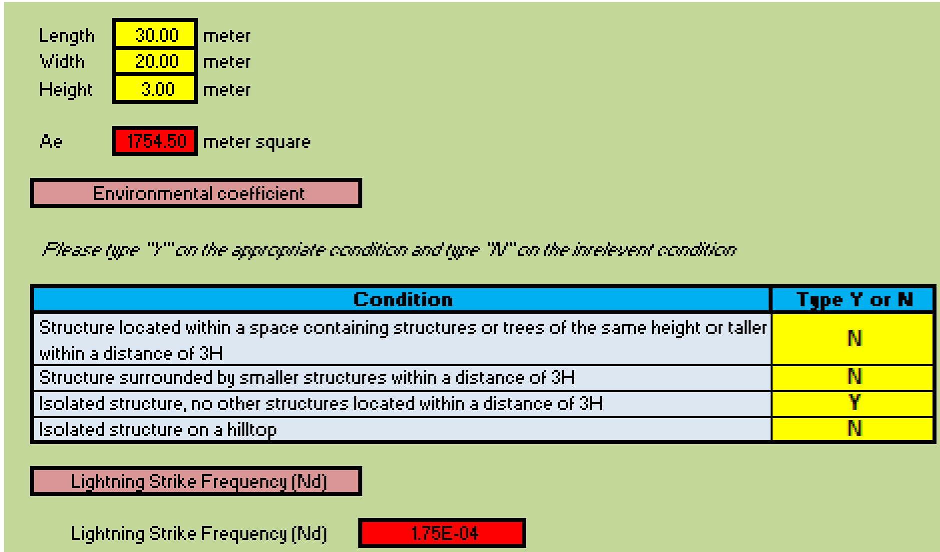

Figure 10: Assessment result for Nd

Based on the tool that had been designed, it was shown that the value of lightning strike frequency, Nd, would get much higher value number if the value of the lightning ground flash density inserted was a big value number. Plus, the value of the equivalent collection area, Ae, would also affect the Nd if the length, width and height of the building structure values are were increased. Location factor coefficient, C1, would also play an important role in contributing to the high value of Nd. It was stated that when the structure location was isolated and at the hilltop, it would gain a higher coefficient by ‘2’ whereas the structure surrounded by taller structure would give smallest value of coefficient by ‘0.25’.

For tolerable lightning frequency, Nc. It was shown that the value would get higher if the total coefficient, C is in small value. Henceforth, coefficient of C2, C3, C4 and C5 are in the state condition of less risk. So, by then the total value of the coefficient would be small. If not, the total value of the coefficient would be largely affected by the higher risks for all conditions which could contribute to the big value of coefficient. By then, it would justify the need to install the LPS for minimum risk avoidance caused by hit of the lightning.

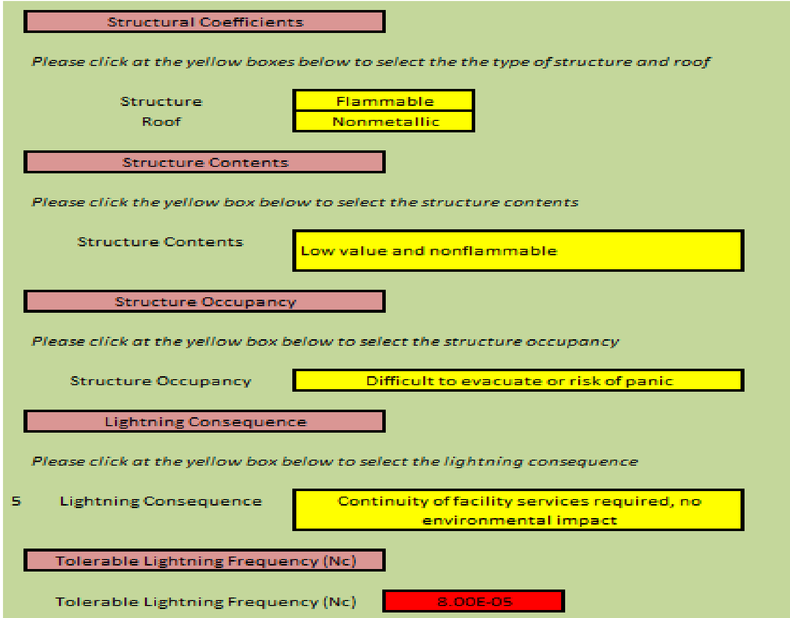

Figure 11: Assessment result for Nc

4.2 Strike Termination Device

The objective of this strike assessment is to identify the possible limitations on how many lightning rods or air terminals should be permitted to install to the building or to be specified, in the building's roof area. The project was focused mainly on three types of the roof which are ridge type, flat and also pitched roof. By the formula stated, the tool was designed and constructed to have the minimum requirement for each type of the roof that was needed based on the required parameters for the users to fulfill which were the length, the width of the roof respectively.

Although the tool was developed in order to define the required air terminal or lightning rods value, nonetheless, the tool still has its own limitation by it is not specified in proper guidelines on how to install the air terminals or lightning rods at each of the roof types'. Nevertheless, the tool was designed to suggest the value required of the lightning rods or air terminal to be installed when the users would be entering the inputs to the perimeters that had been constructed respectively.

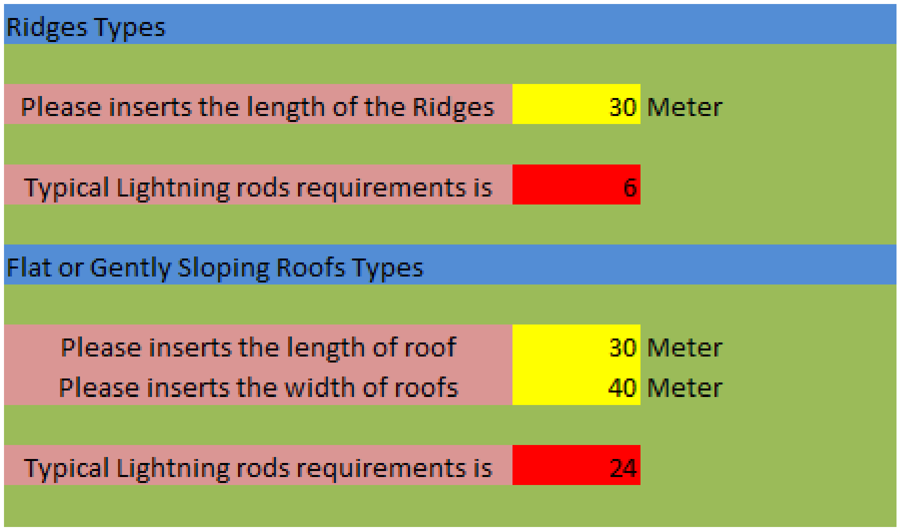

Figure 12: Assessment results for Air Terminal

It is important thing to note that the air terminals or lightning rods should not be less than 10 inches of the height.

Along the way, for some cases, it is happened when the building are coming from multiple-level roof. Hence, for this case, the zone of protection shall be permitted. Within the project scope, it was found that the angle method that using a formula of $x^2 = y^2 + z^2$ was more likely to be used rather than rolling sphere method for multilevel roof zone of protection. By applying the zone of protection, hence, the amount of the air terminals or lightning rods could be minimized. This was due to the length, ‘x’ based on height of both structures that had gained before by applying angle method formula across the safe zone have been covered and no air terminals need to be placed.

4.3 Down conductor

The specifications of the down conductor and air terminals were justified based on criteria of height of the structure building. Which as stated, the specification would be covered for class II materials if the building exceeds 23 meters height. Alternatively, the specifications would be covered by class I material if the building structure height is less than 23 meters.

It could be seen that the height of the building contributed as the main factor in determining the material class type of the air terminals and down conductor specifications. Nonetheless, this project still had its limitation whereby it did not contain sufficient data and information to justify for maximum class materials and also if the perimeters are over design or not. Plus, the project also had its limitation where it did not specify enough on how to install the down conductor along the way from the air terminal to the grounding system based on each type of roof respectively.

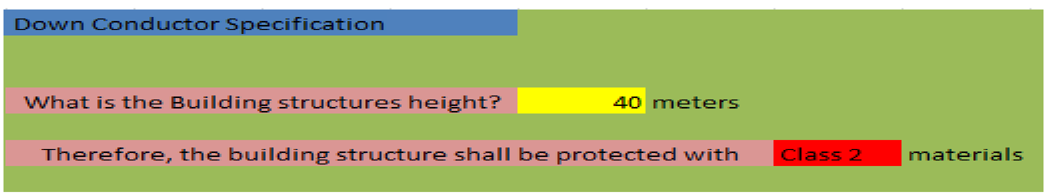

Figure 13: Assessment result for down conductor

4.4 Grounding system

The objective of the grounding system was to identify the appropriate grounding electrode to be selected within certain condition. In detail, the electrode specification should be determined by selection on two criteria which were whether the area is in corrosive environment and also the soil conditions. Based on these two-condition selections, therefore, the grounding electrode specification type could be specified.

It is important to note down that ground electrode should not be less than 12.7 millimeters in diameter and 2.4 meters long and it should extend vertically up to not less than 3 meter into the earth where this condition is fixed.

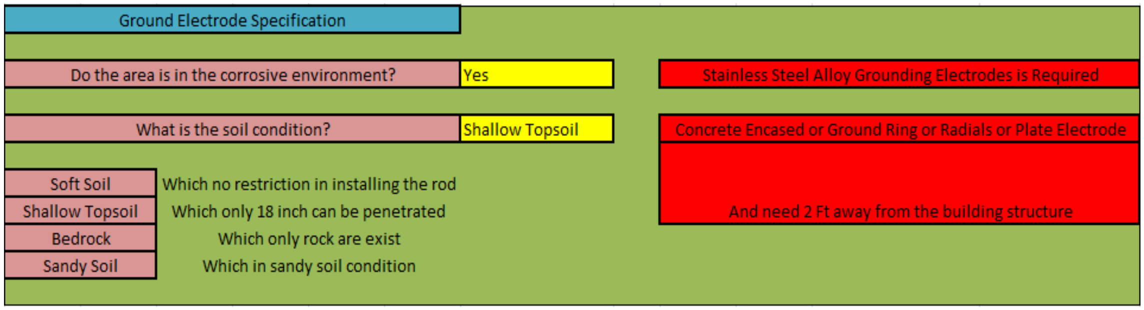

Figure 14: Assessment result for grounding system

CHAPTER 5

CONCLUSION

In conclusion, the LPS tool was successfully produced and could be run smoothly despite some errors and troubleshoots emerged involving the associations between the functions and formulae. Albeit, every output which had been produced based on the input inserted in the respective parameters were done quite well. With this tool produced, it was hoped that the users would find this tool very helpful in understanding the importance of LPS installation onto the buildings which are highly risky to be exposed to the lighting strike phenomenon. Moreover, this tool would enable the users to obtain an idea on how to determine the amount or magnitude of the lightning rods or air terminal for each respective building based on the parameters stated, such as the roofs, the length of the selected roofs, etc. Furthermore, the specification on the down conductor made could be comprehensively understood which were based on the height of the building itself, and could be simply recognized regarding the factors determining the selection of the grounding electrodes made, based on the two factors; which were the corrosive environment area and the soil conditions. Hopefully, with the extensive exposure to this tool, perhaps the users could have a full idea on the LPS itself and its importance and therefore, it could be concluded that the objectives of this project were fulfilled.

CHAPTER 6

RECOMMENDATION

In the future, a further study about the lightning rods or air terminal design or even the types suitable for certain areas could be highlighted due to the fact that different areas would contribute to the different densities of the lightning. By that, we could define and analyze in terms of the durability and the establishment of the lightning rods, so that the efficiency of these rods under the lightning strikes could be optimized. Therefore, it would reduce the possibility/percentage of the divergence of the lightning strikes onto the exposed sides of the building and consequently exposing any possible threats from the occurrence. Apart from that, a more comprehensive study could be done regarding the maximum class material in determining the specifications for the down conductor and also for air terminals or lightning rods. With the respective range of the minimum and maximum ranges specified, therefore the design specifications could be regulated so that it would not exceed/over the design.

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