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LIGHTNING PROTECTION SYSTEM IN MALAYSIA: MATERIALS SELECTION FOR DOWN CONDUCTOR

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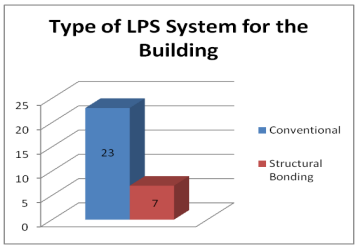
Graphical abstract



Abstract

Lightning is a natural phenomenon that cannot be prevented, therefore the specific system need to be installed in the building to reduce or eliminate the impact of lightning flash and safely discharge to the ground. The country along the equator including Africa, South America and Southern Asia received the highest number of lightning. Malaysia experienced in average of 100 to 140 days of lightning and 600000 to 1300000 number of lightning flash per year. This research is conducted to identify the materials selection for the lightning protection system especially the down conductor cable. Several projects around Malaysia had been selected for this purpose. From the research, they are two types of lightning protection system commonly implemented in Malaysian buildings; the conventional method and structural bonding method. It was found that 23 % of the projects used structural bonding method, mostly from the government projects, and 77% of the projects used conventional method. For the down conductor cable selection, the conventional method used the copper and aluminium tape. And for the structural bonding method the galvanized steel iron was used as the down conductor cable.

Keywords: Lightning, down conductor, conventional, structural bonding

Abstrak

Kilat merupakan fenomena semulajadi tidak dapat dihalang. Oleh itu satu sistem perlu dipasang untuk mengurangkan atau menghapuskan kesan panahan kilat dan disalurkan secara selamat kepada tanah. Negara sepanjang garisan khatulistiwa seperti Afrika, Amerika Selatan dan Asia Tenggara menerima kilat yang tertinggi. Malaysia mengalami secara purata 100 ke 140 hari kilat dan 600000 ke 1300000 jumlah panahan kilat setahun. Kajian ini dilakukan untuk mengenal pasti pemilihan bahan bagi sistem perthanan kilat terutama konduktor bawah. Sebilangan projek di Malaysia telah dipilih untuk tujuan ini. Daripada kajian,terdapat dua jenis sistem pertahanan kilat yang telah dilaksanakan pada bangunan di Malaysia; kaedah konvensional dan kaedah ikatan struktur. Dijumpai 23% daripada keseluruhan projek menngunakan kaedah ikatan struktur yang kebanyakannya terdiri daripada projek kerajaan dan 77% projek menggunakan kaedah konvensional. Bagi pemilihan bahan untuk konduktor bawah, kaedah konvensional memilih kuprum dan aluminium. Dan kaedah ikatan strukur memilih besi keluli galvani sebagai konduktor bawah.

Keywords: Kilat, konduktor bawah, konvensional, ikatan struktur

1.0 INTRODUCTION

Lightning is a natural phenomenon which develops when the upper atmosphere becomes unstable due to the convergence of a warm, solar heated, vertical air column on the cooler upper air mass. These rising air currents carrywater vapor which, on meeting the cooler air, usually condense, giving rise to convective storm activity [1]. This lightning can be one of natural cause of injuries to human or damage of the electrical equipment [2]. According to Lightning Protection Handbook [1], the highest thunderstorm days in the world is around the equator as shown in Figure 1. The highest number of lightning recorded in Africa in average of 200 of lightning days per year follow by Southern Asian and South America. The number of lightning days show that nessecary to protect the building, equipment and human from lightning impact.

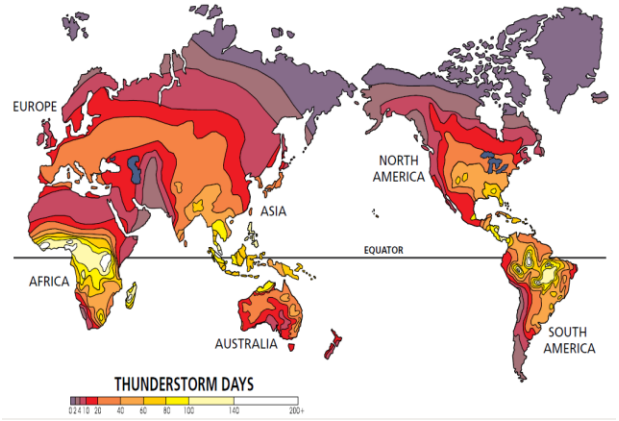


Figure 1 Thunderstorm Days [1]

Malaysia also included as one of the highest days of lightning per year in the world. As shown in Figure 1, the average days of lightning in Malaysia per year is around 100 – 140 days. Studies conducted by Salimi *et al*. [3], describe the details lightning data in Malaysia. For et aPeninsular Malaysia, the highest lightning recorded in Kuala Lumpur with 280 days and lowest Petaling Jaya 71 days of lightning per year.

Table 1 indicate the total number of lightning flash which in the average of 600000-1300000 flash occured in Malaysia in the period of 2008 until 2011. The number of flash highhest in 2008 and lowest in 2010. In Malaysia, the highest amplitude of the lightning was recorded in Pekan Pahang in 2012 with the amplitude of 77kA [4]. According to JKR Specification of Lightning Protection system, amplitude above 1.5 kA was considered as lightning flash [5].

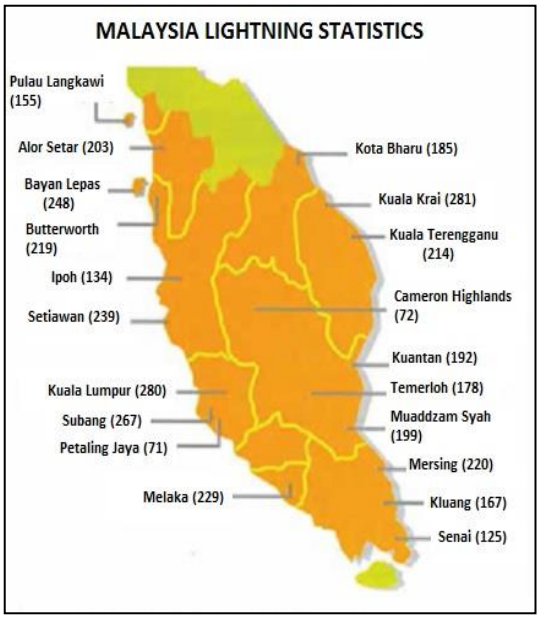


Figure 2 Lightning Days in Malaysia [3]

Table 1 Annual Lightning Flash [6]

Year	Total Flash
2008	1228170
2009	978254
2010	684594
2011	774268
Total	3665286

2.0 OVERVIEW OF LIGHTNING PROTECTION SYSTEM

According to Benjamin Franklin, the first person discovered that the lightning contain electricity in 18th century, they are two purposed of lightning protection system for building. Firstly, even though the occurrence of lightning cannot be prevent, the lightning protection system can provide a specific location for the lightning strike on the building by using air termination rods. And secondly, it will also provide the safe path on the electricity current from the lightning to be smoothly discharge to the earth [7]. The overall function of the lightning protection system can be classified into several functions as indicated below [1];

- Provide the proper point for intercept the lightning strike
- Provide proper path for lightning lightning current to earth
- To dissipate current into the earth
- Create an equipotential bond to prevent hazardous potential differences between LPS, structure and internal elements/circuits.

The selection of lightning protection system is depend on the lighnting protection level (LPL). The

relationship between LPS and LPL can be summarized in Table 2 below.

Table 2 Relationship between Lightning Protection Level, Lightning Protection System and Lightning Parameter [8]

Lightning Parameter (Current Peak Value, kA)	Lightning Protection Level (LPL)	Lightning Protection System (LPS)
200	1	i
150	2	ii
100	3-4	iii-iv

The conventional lightning protection system consist on the three major parts; air termination system, down conductor and earth termination system as shown in Figure 3.

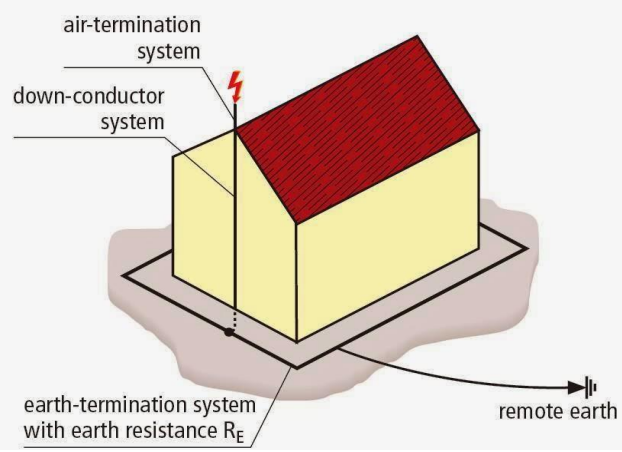


Figure 3 The Conventional Lightning Protection System [9]

The conventional lightning protection is combination of the franklin rods and faraday cage method. As Benjamin franklin discovered the lightning should have a specific point to strike before safely flowed the electrical charge into earth, the specific rods called as franklin rods has been introduced. Figure 4 demonstrates the protection angle, rolling sphere and mesh method.

The air termination system can be designed by using Protection Angle Method (Franklin Rods), Mesh Method (Faraday cage) and Rolling Sphere Method. In the protection angle method the, the angle of the protection is depend on the height of building and class of LPS [10]. For the mesh method and rolling sphere method, the mesh size and radius of sphere depend on the class of LPS [1].

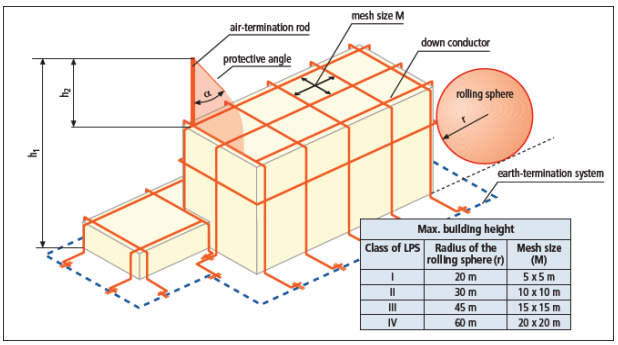


Figure 4 Protection Angle, Rolling Sphere and Mesh Method [1]

For conventional lightning protection method, the system start from air termination at the top of building before going down to down conductor at externally of the building wall or structure before discharge to the earth by the earth termination system as been shown in Figure 5. This method had widely used in the world and Malaysia.

Figure 5 Conventional method [11]

For the structural bonding system is the method where the LPS cable concealed within the reinforced concrete structure as been shown in Figure 6. In this method, the air termination system will be connected with the lightning protection system embedded in the reinforcement steel bars in the concrete column, ground beam and pad footing before discharge to the earth. Guideline by Public Work Department Malaysia [5] allowed this method to be implemented in the construction practice. Recently, the number of project implemented this method had been widely increased.

Figure 6 Structural bonding method [11]

3.0 METHODOLOGY

3.1 Work Procedures

This research is focusing on the materials used as the down conductor for the lightning protection system in Malaysia. Several procedures that must be followed to investigate the materials selection such as identification of the project, site visit, visual inspection, study on drawing and data collection.

3.2 Data Collection

Before the data collection can be obtained, several site in Malaysia has been selected to be analyzed the data for the material of down conductor in the lightning protection system. The data collection start with site visit, study the drawing for lightning protection system and visual observation.

3.2 Data Analysis

To analyze the data, the data will be classified with different type of building, owner of the building, down conductor materials and clamping for the down conductor.

4.0 RESULTS AND DISCUSSION

List of project tabulated in Table 3. Total 30 number of project had been investigates to complete this research. The project included government and private projects with various type of buildings.

Table 3 List of Project

No.	Project	Owner	Type of Building
1	KTMB Staff Quarters, Alor Setar Kedah	Private	Quarters
2	Administrative Building for IKM, Pulau Pinang	Government	Government Office
3	Student Hostel for IKM, Pulau Pinang	Government	Hostel
4	Administrative Building for Kem Tentera Darat,Perlis	Government	Government Office
5	Officer Quarters for Kem Tentera Darat,Perlis	Government	Quarters
6	Surau for Kem Tentera Darat,Perlis	Government	Mosque/Prayer Room
7	Student Hostel for Kolej Pertanian Lumut, Perak.	Government	Hostel
8	Administrative Building for Kolej Pertanian, Lumut, Perak	Government	Government Office
9	Kompleks Kota Darul Naim, Kelantan	Private	Commercial Building
10	3-storey shops and office, Arau, Perlis	Private	Commercial Building
11	8-storey apartment Mukim siding, Perlis	Private	High Risk Building
12	Hotel Wakaf, Taiping, Perak	Private	High Risk Building
13	Masjid Al-Kurawi, Batu Kurau, Perak	Private	Mosque/Prayer Room
14	Aeon-Big Alor Setar, Kedah	Private	Commercial Building
15	Padang Besar KTMB Staff, Perlis	Private	Quarters
16	8-storey Business suites, Taiping, Perak	Private	High Risk Building
17	4-storey Car Park Building , Taiping, Perak	Private	Commercial Building
18	Single Storey Shoplot, Taiping Perak	Private	Commercial Building
19	8-storey Budget Hotel, Taiping, Perak	Private	High Risk Building
20	Hostel KPM, Melaka.	Government	Hostel
21	Administrative Building KPM, ,Melaka.	Government	Government Office
22	Perpustakaan Awam Negeri Pahang	Government	Government Office
23	Headquarters Lembaga Pelabuhan Johor, Pasir Gudang, Johor.	Government	Government Office
24	Administrative Building for IKBN Hulu Langat, Selangor	Government	Government Office
25	Hostel for IKBN, Hulu Langat, Selangor	Government	Hostel
26	20-Storey office at damansara kuala lumpur	Private	High Risk Building
27	Bio Laboratory for Jabatan Perikanan, Johor.	Government	Government Office
28	Kementerian Dalam Negeri Kangar Perlis	Government	Government Office
29	Market Sri Bdr Butterworth, Penang	Private	Commercial Building
30	5-storey house at Taman Free School, Penang.	Private	High Risk Building

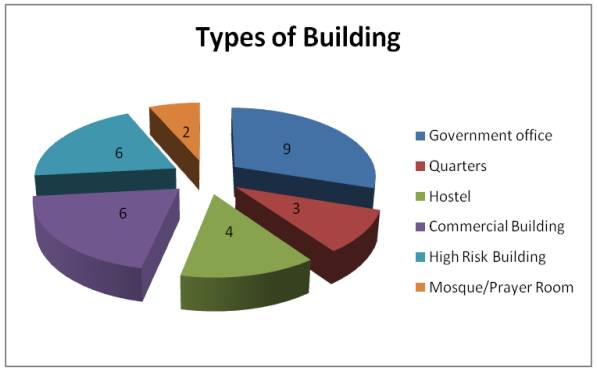


Figure 7 Types of building

As overall, 15 projects were governments and 15 private projects involved. As shown in Figure 7, nine projects is for government office, follow by commercial and high risk building 6 projects, student hostel 4 projects, quarters 3 projects and the remaining 2 projects were mosque/prayer room. Table 4 demonstrates the lightning protection method, down conductor and clamping for the projects.

Table 4 Lightning Protection Method, down conductor and clamping for the projects

No.	Lightning Protection Method	Down conductor cable	Clamping
1	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
2	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
3	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
4	Structural Bonding	Galvanised Steel Iron (GI) 50 mm Diameter	U-Clamp to steel reinforcement
5	Structural Bonding	Galvanised Steel Iron (GI) 50 mm Diameter	U-Clamp to steel reinforcement
6	Structural Bonding	Galvanised Steel Iron (GI) 50 mm Diameter	U-Clamp to steel reinforcement
7	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
8	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
9	Structural Bonding	Galvanised Steel Iron (GI) 50 mm Diameter	U-Clamp to steel reinforcement
10	Conventional	Copper Tape 25mm x 3mm	PVC trunking cable
11	Conventional	Copper Tape 25mm x 3mm	PVC trunking cable
12	Conventional	Copper Tape 25mm x 3mm	PVC trunking cable
13	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
14	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
15	Conventional	Aluminium Tape 25mm x 3mm	Saddle tape
16	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
17	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
18	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
19	Conventional	Aluminium Tape 25mm x 3mm	Aluminium Saddle tape
20	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
21	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
22	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
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29	Conventional	Copper Tape 25mm x 3mm	Copper brass saddle
30	Conventional	Copper Tape 25mm x 3mm	PVC trunking cable

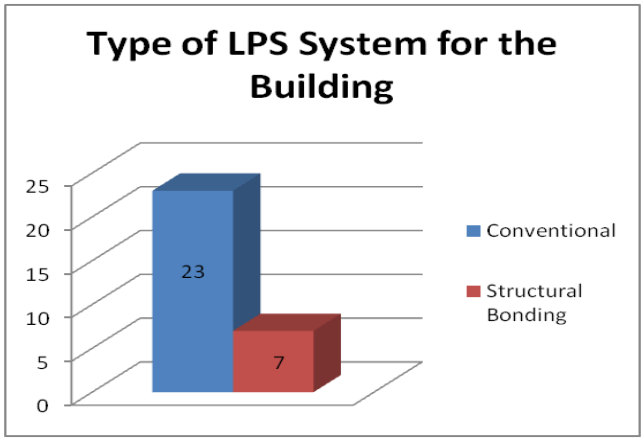

Figure 8 Types of Lightning Protection System

From total number of 30 projects, 23 projects use the conventional method and 7 projects are equipped with structural bonding method for the lightning protection system as shown in Figure 8. Most of the projects installed with conventional method are from the private sector i.e. 14 out of 23 projects. Only 9 projects from government used this method.

This is because the structural bonding method is still new in Malaysia and for the private sector is it not

essential to follow new method; therefore most of private projects remain using the old practice, the conventional method. For the structural bonding method, 5 projects are from government and only 2 projects from private. Government projects started to implement the structural bonding method because of the new guidelines by public work department which allow the lightning conductor cable to be concealed in the concrete structure. Some of the benefit of this method is that it can reduce the number of thief activities for the lightning protection system cables and can save construction times, because the cabling could be completed after the concreting process. Compared to the conventional method, single time is needed to install the lightning protection system. Other benefit is the esthetic appearance on the final surface of the building, with the structural method there is no down conductor cable arrangement can been seen. Therefore most of the government projects choose to use the new method of installation the lightning protection system.

The materials selection for the down conductor can be classified into three major categories, namely copper tape (25 mm x 3 mm size), aluminum tape (25 mm x 3 mm size) and galvanized steel iron (GI) with 50 mm diameter. Figure 9 shows the copper and aluminum tape while Figure 10 shows the falvanised steel iron with u-clamp.

Figure 9 Copper & aluminum tape (25 mm x 3 mm)

Figure 10 Galvanized Steel Iron (50 mm diameter) with U-Clamp

From the Figure 11, 16 projects used copper tape as the down conductor cable. The copper and aluminum tape were used in the conventional method and galvanized steel iron used in the structural bonding method. All government projects used copper tape as the down conductor for conventional method. Meanwhile all 7 projects used aluminum tape from the private sector, and 6 project private used copper tape. The reason all government projects used copper tape is because of the low resistance and high conductivity of copper compare to aluminum. Even thought, the price of the copper is higher than aluminum, the quality and performance of the cable is the most priority in selecting this material for down conductor of government project. For the structural bonding method, all 7 projects used 50 mm diameter galvanized steel iron as the down conductor cable. According to Public work department specification, 50 mm diameter is the minimum diameter for the down conductor embedded in the concrete structures. The galvanized steel iron was selected as the cable to be combined with steel reinforcement in the structure using U-clamp. It is popular among various designer or engineer because of the material similarity with the steel reinforcement.

Figure 11 Clamping for down conductor

For the types of clamping, 4 types of clamps were identified in this research. They are aluminum and copper saddle tape, U-clamp to steel reinforcement and PVC trunking cable. All government projects for the conventional method used copper saddle tape as the clamping method. And the rest 4 private projects with copper tape used PVC trunking cable as clamping materials to cover the copper tape with the trunking cable. For the aluminum tape cable, the aluminum saddle was used to clamp the tape to the wall or structures of the building. Figures 12 and 13 show the aluminum and copper saddle tape and PVC trunking cable. For the structural bonding method, all projects used the U-clamp as the medium to clamp the cable with steel reinforcement within the structures.

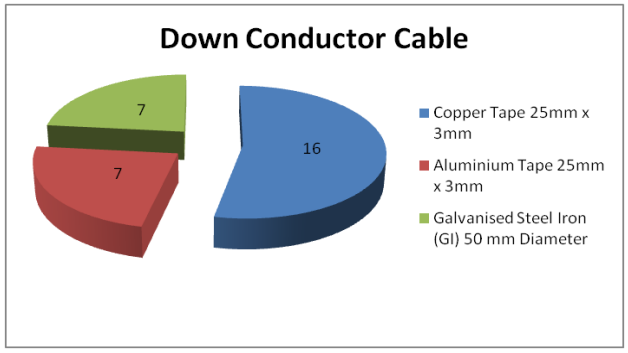

Figure 12 Down conductor cable

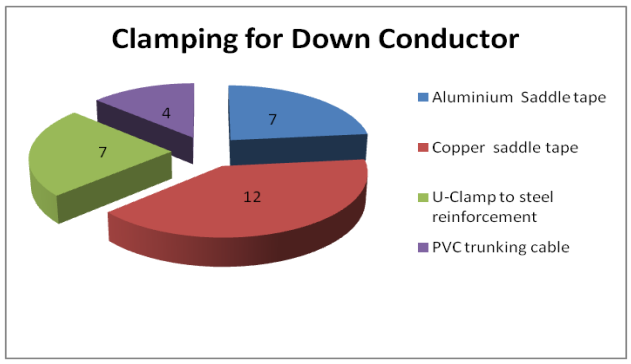

Figure 13 Copper & aluminum saddle tape

5.0 CONCLUSION

Lightning protection system in the Malaysian buildings is crucial due to the frequently occurred lightning flash. Even thought the structural bonding method is still new in Malaysia, the number of project installed using this method is around 23% or 7 out of 30 projects. Most of the project used traditional method because lack of expertise to install and design the structural bonding method. Because of the benefit of structural bonding method such as time saving, cost saving, esthetic appearance and safety most of the government projects start to implement the structural bonding method. Galvanized steel iron has been chosen to be use as down conductor for the structural bonding method because of the materials of galvanized steel iron is similar with the steel reinforcement. Both materials can be bound together in the structure using u-clamp. For the conventional method, copper is the most selected for the down conductor cable as the copper can give more electrical conductivity and low resistance. Meanwhile all the private projects used aluminum tape as the down conductor cable as the price could be the factor. As for the clamping device, most of the projects included government and private project used the copper and aluminum saddle tape to locate the tape at the wall or structures in the building. In conclusion most of government project start has started to implement the structural bonding method as the lightning protection system. Meanwhile, in all structural bonding method projects, the galvanized steel iron has become the material of preference as the down conductors.

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