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Comparative Study between Structure Bonding Method and Conventional Method for Lightning Protection System

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ABSTRACT

This paper presents the comparative study between structure bonding method and conventional method for lightning protection system (LPS). LPS is utilized to prevent any harm to the structure due to lightning strike. There are two types of LPS methods which are currently being used by the Malaysian Public Works Department (also known as Jabatan Kerja Raya or JKR). The methods are structure bonding method and conventional method. Both LPS methods must have earth electrode resistance less than 10Ω. In order to evaluate the methods, measurements of the earth electrode resistance using Digital Earth Tester Kyoritsu Model 4105A are conducted. It is found that the average earth electrode resistance for conventional method is 4.29Ω while the average earth electrode resistance for structure bonding method is 1.76Ω. Based on the average earth electrode resistance, we found that structure bonding method has a lower earth electrode resistance compared to the conventional method.

Key words: earth electrode resistance, conventional method, structure bonding method, lightning protection system (LPS).

1. INTRODUCTION

Lightning is one of the most destructive phenomena in the world. Its release contains amazing measures of electrical vitality and has been estimated to produce current from a few thousand amps to more than 200,000 amps. Even though a lightning release is only of a brief length, it can cause severe harm and devastation. Consequently, LPS is required in order to protect structures against the damaging effects of lightning [1]. Sha'ri et al. [2] stated that an external lightning protection system (LPS) is intended to intercept lightning flash to the structure using an air-termination system, conduct the lightning current safely towards the earth using a down conductor system and disperse lightning current to earth using an earth-termination system. Dealing with a dispersion of lightning current (high-frequency behavior) into the ground, whilst minimizing any potentially dangerous overvoltage, the shape and dimension of the earth termination system are important. According to Anggoro [3], the grounding system of LPS must have a very low impedance at high frequency.

LPS methods can be divided into two types which are structure bonding method and conventional method [2]. The conventional method employs copper tape as the down conductor which is attached to the external of the building. Copper has been the metal of choice for current carrying conductor in the electrical industry. With the interest in copper consistently expanding, the overall cost of copper is on the rise. The high price of copper is the main reason why copper is prone to theft as it could give thieves a very high income per copper [4]. Due to the location of the down conductor of LPS conventional method that is clearly seen, it is prone to theft. On the other hand, when lightning strikes the sides of the building, it tends to strike the LPS directly and as a result, the structure of the building is not damaged [5].

The structure bonding method employs steel wire as the down conductor which are installed within the building. Since the down conductor is clamped onto the support structure within the building itself, it is not exposed. It is therefore much safer and the chances of the down conductor being stolen will be minimized. However, due to the location, when lightning strikes the sides of the building, it will directly hit the building and as a result, the structure of the building may get damaged.

The purpose of this paper is to study the LPS which are mainly used for every structure in Malaysia and is much needed in order to protect the building from any damage due to the lightning strike. Hence, the objectives can be listed as follows:

i) To conduct a comparative study between the LPS of structure bonding method and the conventional method based on the data collected from the Malaysian Public Works Department (JKR)

ii) To determine which LPS provides lower earth electrode resistance based on earth electrode resistance.

2. METHODOLOGY

This section presents the flow of the measurement process in order to measure the earth electrode resistance.

The process of data measurement of the earth electrode resistance is shown in Figure 1. The data measurement is using a fall-off potential method [6], [7]. This method uses Digital Earth Tester Kyoritsu Model 4105A. It comes with two additional auxiliary spikes which act as a potential spike and a current spike [8]. Both spikes will be embedded on the ground. Potential auxiliary spike (P) is set between current auxiliary spike (C) and earth electrode (E) Alternating voltage named as 'e' is applied between E and C. By using AC meter, resultant current is measured. Next, the value of voltage will be measured using a voltmeter in between of E and P and hence the value of earth electrode resistance (R) obtained from the equation of V = IR.

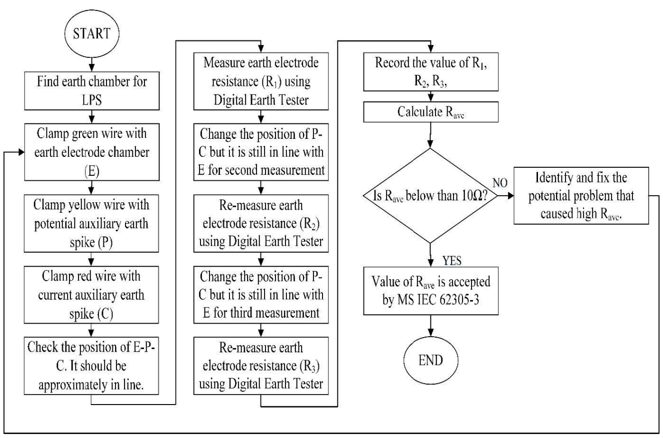

Figure 1: Flowchart of the measurement process

In order to record the earth electrode resistance, the first step is to find the right earth chamber. Earth chamber that needs to be located is the earth chamber for LPS. The green coloured wire is paired with the earthed electrode (E) located in the earth chamber, the auxiliary spike is embedded on the ground and one spike represents current and another one represents potential. The red wire is paired with the current spike (C) while the yellow wire is paired with the potential (P) spike. Each spike is located 5m to 10m away from each other and E-P-C should be approximately in line [9]. The position of P-C will be changed two times and earth electrode resistance will be re-measured. The earth electrode resistance reading is taken for three times and the average reading (R_{ave}) will be calculated. The process ends if R_{ave} is lower than 10 Ω. One must locate the potential issue if the value of average resistance is greater than 10Ω. The potential problem might be due to the type of resistivity, missing copper tape in the component of LPS, an insufficient amount of earth electrode at earth chamber, and galvanic corrosion of underground conductor.

3. RESULTS AND DISCUSSION

In this section, data collection from the measurement works are presented. The data are measured at 30 different places for conventional method and two different places for structure bonding method. Another 16 data for structure bonding method are collected directly from the JKR as the measurement process were done by JKR previously.

3.1 Earth Electrode Resistance

The values of the earth electrode resistance for all structures are shown in Table 1 for structure bonding method and Table 2 for conventional method.

Table 1: Earth electrode resistance of LPS using a structure bonding method for all structures

Types of Building	Building name	Earth Electrode Resistance (Ω)			
		R_1	R_2	R_3	R_{ave}
Mosque	Masjid Taman Jaya Kuala Terengganu				0.80
	Masjid Tok Randok Hulu Terengganu				1.20
	Masjid Banggol Tok Esah Kuala Terengganu				1.20
	Masjid Sultan Muhammad Bukit Besar Kuala Terengganu				2.00
	Masjid Seberang Takir Kuala Terengganu				2.00
	Masjid Payang Kayu Hulu Terengganu				3.20
Government Quarters	Kuarters Kastam Pengkalan Gawi Kenyir				2.00
Government Buildings	Perpustakaan Awam Negeri Pahang	0.00	0.00	0.00	0.00
	Jabatan Kastam Diraja Malaysia	1.60	1.50	1.70	1.60
	Pasar Langkap Setul				1.70
	MBKT Kuala Terengganu				2.50
University Building	Kolej Nilam UiTM Pulau Pinang Kampus Permatang Pauh				1.80
	Kolej Kristal UiTM P.Pinang Kampus P. Pauh				2.30
	Kolej Intan UiTM P.Pinang Kampus P. Pauh				3.00
Complex	Blok 8 Kompleks Kota Darul Naim				0.26
	Kompleks Pekan Rabu				3.00

Table 2: Earth electrode resistance of LPS using conventional method for all structures

Types of Building	Building name	Earth Electrode Resistance (Ω)			
		R_1	R_2	R_3	R_{ave}
Mosque	Masjid Saidina Umar Al-Khattab	2.70	2.00	3.00	2.60
	Masjid KUIPSAS	5.00	2.00	6.00	4.30
	Menara Masjid KUIPSAS	6.00	4.00	3.00	4.30
Government Quarters	Blok F Kuarters Kurnia	6.00	7.00	5.00	6.00
	Blok G Kuarters Kurnia	8.00	6.00	8.00	7.30
Government Buildings	Pejabat Pengarah Tanah dan Galian Negeri Pahang	0.00	0.10	0.00	0.03
	Jabatan Kimia Malaysia	0.00	0.50	0.60	0.37
	Klinik Kesihatan Indera Mahkota	0.20	0.40	0.55	0.40
	Jabatan Kesihatan Negeri Pahang	0.50	0.30	0.80	0.60
	Suruhanjaya Pencegahan Rasuah Malaysia	1.30	1.00	2.00	1.40
	Jab. Ketua Pengarah Tanah & Galian (Persekutuan) Negeri Pahang	1.70	1.90	1.50	1.70
	Arkib Negara Malaysia Negeri Pahang	1.20	3.00	3.50	2.60
	Jabatan Mineral Geosains	3.10	4.50	5.00	4.20
	Rumah Kanak-kanak Tengku Ampuan Fatimah	5.00	3.00	6.00	4.70
	Pejabat Daerah dan Tanah Kuantan	6.80	8.00	5.50	6.80
	Klinik Kesihatan Kurnia	9.00	8.00	8.00	8.30
	Jabatan Pendidikan Negeri Pahang	9.00	9.70	8.00	8.90
	Dewan Jubli Perak Sultan Haji Ahmad Shah	14.00	11.00	15.00	13.30
University Building	Dewan Ibnu Khaldun	0.00	0.00	0.20	0.10
	Kolej Kemahiran Tinggi Mara	0.00	0.50	0.00	0.20
	Auditorium KUIPSAS	0.00	0.00	0.80	0.30
	PSI KUIPSAS	1.00	0.00	2.00	1.00
	Kolej Poly-Tech Mara	4.00	6.00	3.00	4.30
Complex	Kompleks Penyayang	0.50	0.30	0.70	0.50
	Kompleks KDN Negeri Pahang	1.00	0.80	2.50	1.40
School	SBP Integrasi Kuantan	8.70	7.00	9.50	8.40
	SJK(T) Bandar Indera Mahkota	9.20	10.00	8.00	9.10
	SK. Tunku Azizah	10.30	9.00	8.50	9.30
	SK. Indera Mahkota Utama	13.80	15.00	12.00	13.60

Table 1 shows the result of the earth electrode resistance by using a structure bonding method. The range of arithmetic mean is from 0.00 Ω to 3.20 Ω. This shows that all reading is below 5 Ω which is good to conduct lightning current safely to earth. The age of the building and the location of the building are not going to be the reason of high average reading. The installation of LPS for this method is located inside of the building which, the LPS is being clamped onto the support structure and hence it will not be facing any rust issue due to air or water moisture. Besides that, the installation of LPS for structure bonding method is starting from the beginning of the support structure, and hence due to that, this method is not facing any problem regarding the type of soil which results in a very good earth electrode resistance reading.

Table 2 shows the earth electrode resistance values for all structure for LPS using the conventional method. The range goes from 0.03 Ω until 13.60 Ω. The average value may differ depending on the type of soil surrounding the building, the age of the building, the location of the building, the depth of copper rod in the soil and a total number of copper rod used for certain buildings. In general, the higher the moisture content, the lower its resistivity [10]. Besides that, the deeper the copper rod and the higher the number of electrodes used, the lower the earth electrode resistance. By using this method, the age of the building may become one of the reasons for high R_{ave}. This is because, the older the building, the higher the possibilities for the copper becomes rusty due to exposure towards air or water moisture. The copper tape is also exposed to being stolen. While for the location of the building, if the building is located up in the hill, the R_{ave} will become higher. This where the depth of the copper rod gives a huge difference in the R_{ave}. As stated before, the deeper the copper rod, the more effective to lower the earth electrode resistance.

3.2 Comparison of Earth Electrode Resistance Based on Building Types

The comparison of earth electrode resistance reading based on the building types is shown in Figure 2.

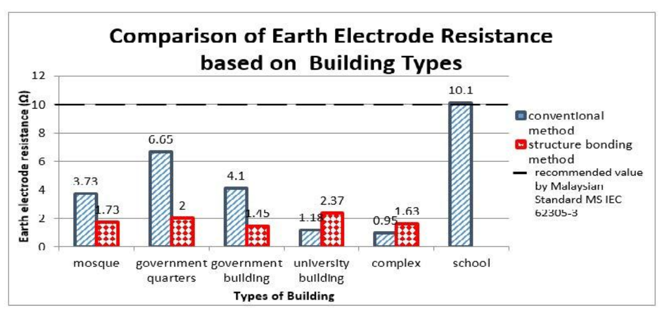

Figure 2: Comparison of earth electrode resistance based on building types

Figure 2 shows the comparison data of earth electrode resistance based on its type of building. The comparison is between the conventional method and structure bonding method. As shown above, there are five data that can be compared, and one data cannot be compared as the data for another method is not available. Three out of four data compared show that the values of the earth electrode resistance of structure bonding method are lower than the conventional method. Data on earth electrode resistance for the structural bonding method is the lowest. As stated in Figure 2, the recommended value of earth electrode resistance by MS IEC 62305-3 is 10 Ω. The earth electrode resistance shown in the graph are below the recommended value which is already good enough to transport the lightning current safely to the earth. But, note that the lowest the earth electrode resistance, the easier the lightning current can flow to the earth. This shows that the lower the value of the earth electrode resistance, the preferable the method is.

4. CONCLUSION AND RECOMMENDATIONS

The objective of this research is to conduct a comparative study between LPS of structure bonding method and the conventional method. The comparative study helps to identify which LPS is preferable to be used in the future. Both methods have their own advantages and disadvantages, hence in order to strengthen the comparative study, measurements of the earth electrode resistance were conducted. There were 30 R_{ave} for conventional method and 16 R_{ave} for structure bonding method to be compared. Based on the comparison of earth electrode resistance with separated and unseparated type of building, it was found that structure bonding method has a lower earth electrode resistance compared to the conventional method. In general, structure bonding method is not affected by the type of soil, the age of the building, the location of the building, the depth of the copper, the insufficient number of earth electrode, rust of the copper or the potential of copper getting stolen. While for conventional, the method is affected by the type of soil, the age of the building, the location of the building, the depth of the copper rod, the insufficient number of earth electrode resistance, rust of the copper and the potential of the copper tape getting stolen. Besides that, if the copper tape gets stolen, it increases the cost of LPS because it needs to be replaced in order to reduce the potential the lightning current to affect the building and its surrounding.

From the results, it can be seen that even though structure bonding method has a lower earth electrode resistance compared to conventional method, the value of the earth electrode resistance for conventional method is still acceptable and below the required value which is 10 Ω [2]. Hence, the conventional method can still be applied in the future with some improvement. The main problem of the conventional method is that its copper tape that acts as down conductor, can be easily stolen and get rusted. In order to overcome these, the copper tape that acts as down conductor can be planted in the cement to make it less visible.

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