INVESTIGATION ON ELECTRICALLY CONDUCTIVE AGGREGATES AS GROUNDING USING ACTIVATED CARBON AND PYROLYTIC CARBON

TENGKU HAFIDATUL HUSNA BINTI
TENGKU ANUAR

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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(Student's Signature)

Full Name : TENGKU HAFIDATUL HUSNA BINTI TENGKU ANUAR

ID Number : AA15303

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TENGKU HAFIDATUL HUSNA BINTI TENGKU ANUAR

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ABSTRAK

Tujuan utama sistem pembumian adalah untuk menyebarkan aliran caj ke muka bumi dalam masa yang paling singkat ketika berlakunya kilat ataupun litar pintas. Sistem pembumian berfungsi sebagai perlindungan kilat dalam kilang perindustsrian dan loji kuasa. Oleh itu, sejumlah besar kajian telah dijalankan bagi mencari bahan yang boleh digunapakai untuk sistem pembumian. Karbon aktif dan karbon *pyrolytic* digunakan bagi meningkatkan prestasi sistem pembumian. Kajian ini dijalankan bagi menentukan sifat fizikal bahan tersebut, mewujudkan ciri serapan air lengkung pada peratusan air yang berbeza serta mengenalpasti keberintangan elektrik, penyerapan air dan kekuatan bahan. Terdapat dua jenis karbon yang digunakan dalam kajian ini ialah karbon aktif dan karbon *pyrolytic*. Bahan ini digunakan dalam dua keadaan iaitu serbuk dan aggregat. Karbon serapan air lengkung (CWRC) dibentuk dengan WP4C dan keberintangan elektrik telah dikaji dengan menggunakan kaedah kotak tanah. Kesan karbon aktif dan karbon *pyrolytic* pada keberintagan elektrik, penyerapan air dan kekuatan bahan telah dijalankan. Bagi karbon aktif, pada hari ke-28, 228.6 Ω.m keberintangan elektrik, 12.11% penyerapan air, dan 10.31 N/mm^2 kekuatan bahan. Disamping itu, karbon *pyrolytic* pada hari ke-28 menunjukkan 218 Ω.m keberintangan elektrik, 13.27% penyerapan air dan 10.26 N/mm^2 kekuatan bahan. Karbon aktif dan karbon *pyrolytic* boleh digunakan sebagai bahan alternatif sebagai GEM. Perbandingan antara kedua bahan menunjukkan karbon *pyrolytic* lebih baik berbanding karbon aktif pada semua keadaan. Secara keseluruhan, karbon *pyrolytic* dalam bentuk serbuk mengatasi bentuk aggregat.

ABSTRACT

Electrical earthing system main purpose is to disperse flow of charge to mother earth within the shortest time possible at the event of lightning or fault. Earth grounding assists a lightning-protection in industrial and power plants. Thus, there have been several studies on several materials in order to find the best performing materials for an earthing system. Activated carbon and pyrolytic carbon are used to improve the performance of earth grounding system. The study aims to determine the physical properties and characteristic of materials, establish carbon water retention curve at varying percentage of water content as well as identify the electrical resistivity, water absorption and crushing strength. Two carbon were used in this study namely, activated carbon and pyrolytic carbon. These materials were tested under powder and aggregated form. The samples carbon water retention curve (CWRC) was established by WP4C and electrical resistivity were studied by using soil box method. The effects of activated carbon and pyrolytic carbon on electrical resistivity, water absorption and crushing strength were studied. For activated carbon, at days 28 exhibited 228.6 Ω.m electrical resistivity, 12.11% water absorption and 10.31 N/mm^2 crushing strength. Morever, the effect of pyrolytic carbon at days 28 exhibit 218 Ω.m electrical resistivity, 13.27% water absorption and 10.26 N/mm^2 crushing strength. Lastly, activated carbon and pyrolytic carbon can be used as an alternative material as ground enhancement material. Comparison for both materials, pyrolytic carbon performed better that activated carbon under all testing conditions. Overall, pyrolytic carbon in powder form outperformed the aggregated form.

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LIST OF SYMBOLS

$\Omega.m$	Ohm.meter
C	Celsius
K	Kelvin
μm	Micrometer
w_s	Specific gravity
w	Water content
T_s	Sample temperature
T_b	Chamber temperature
WA	Water absorption
M_{dry}	Mass of dry
M_{sat}	Mass of saturated
$\%$	Percentage
Pc	Load of fracture
X	Diameter
π	Pi
$\pm$	Plus-Minus sign

LIST OF ABBREVIATIONS

SWRC	Soil-water Retention Curve
CWRC	Carbon water retention curve
OPC	Ordinary Portland cement
IEEE	Institute of Electrical and Electronics Engineers
ASTM	American Society for Testing and Materials
BS	British Standard
ISO	International Organization for Standardization
BET	Brunauer-Emmett-Teller
GEM	Ground Enhancement Material
WP4C	Water Potential Meter
AC	Activated carbon
PC	Pyrolytic carbon
Pa	Pascal
N	Newton

CHAPTER 1

INTRODUCTION

1.1 Background

A system of electrical connections to the general mass of earth is known as earthing or grounding where it is to provide direct path for the fault currents to the soil while maintaining the step and touch voltages at acceptable values (Dhrmadasa, 2011). Earth grounding system assists a lightning-protection in industrial and power plants in order to allocate large impulse currents during a lightning strike. The current could flow and induce large transient voltage before dissipate into soil (Liu *et al.*, 2001). According to (Ahmeda, 2012), high voltage transmission and distribution systems require lightning protection and insulation coordination schemes to protect personnel and power system equipment from danger and damage. The earthing of electrical installations is one of the prevention of electrical shock risks to life (Laver and Griffiths, 2001).

In soil resistivity, there are two types of electrical conduction in rocks and soils, electronic conduction and ionic conduction where electronic conduction is the transfer of charges through a solid while ionic conduction is the transfer of ionic charges in a polar liquid such as rainwater (Laver and Griffiths, 2001). However, in some specific applications, there is interest that the resistance value of the grounding system is high (Arias Velásquez et al., 2019), thus, when a high resistance value is adopted for a nearby grounding system, the flow of current are capable to generate (Silveira *et al.*, 2012).

According to Dhrmadasa, (2011), one of the major parameters to determine the performance of the grounding system is the resistivity of local soil. Resistance grounding system is classified as high resistance and low resistance grounding where high resistance is obtained by connecting a high resistance in between the neutral point of low voltage transformer and low resistance is obtained by connecting a small value of the resistance with the grounding conductor or rod (Salam and Rahman, 2016). According to Fukue *et al.*, (1999), the resistivity of soil is influenced by the pore fluid, porosity, grain size distribution, and so on. The resistivity of earth varies with the type of soil water content, temperature, mineral content and compactness (Dale *et al.*, 2017). Most commonly, ground enhancement materials or backfill material are used to enhance the grounding system to attain the required ground electrode resistance (Dale et al., 2017). Due to the high cost of material and space limitation, it become a new practice by using the ground enhancement material to reduce the earth resistance. A good ground enhancement material should provide low earth resistance over a long period with little variation of resistivity value (Gomes *et al.*, 2010).

Electrically conductive cementitious material are used by adding conductive materials which can significantly reduce the resistivity(Chen *et al.*, 2017). Graphite is one of the conductive material used in practical engineering due to its good conductivity and low cost, while with addition of graphite will decreased the compressive strength, flexural strength and bending strength of cement-based material (Wang *et al.*, 2019). Concrete containing conductive aggregates possesses increased the conductivity with a resistivity value of 0.1 to 0.3 Ω.m but relatively low compressive strength which is less than 25 MPa (Wu *et al.*, 2015).

In this study, activated carbon and pyrolytic carbon used as ground enhancement material. Similarly, the materials used with the ordinary Portland cement (OPC) as conductive aggregate. Several tests such as water content, particle size distribution, specific gravity and BET surface area are carried out. Carbon water retention curve (CWRC) is established to determine the improvement of carbon-based at varying percentage of water content. Lastly, electrical resistivity, water absorption and crushing strength are determine in aggregated form.

1.2 Problem Statement

Due to the condition and geotechnical characteristic of the soil, the resistivity is varying depends on the various types of soil at different site location. Carbon based materials such as activated carbon and pyrolytic carbon maybe used to improve the resistivity of the soil in trouble environment.

1.3 Research Objectives

The objectives are as follows:

1. to determine the properties and geotechnical characteristics of activated carbon and pyrolytic carbon.
2. to established carbon water retention curve (CWRC) of activated carbon and pyrolytic carbon at varying percentage of water content.
3. to identify the electrical resistivity, water absorption and crushing strength by using semi-dry mixing and pelletization technique.

1.4 Scope of Study

In this study, two types of carbon-based material samples are used, namely activated carbon and pyrolytic carbon. These materials are tested under powder and aggregated form. The resistivity, carbon-water retention curve, water absorption and crushing strength were tested under condition. Carbon-water retention curve (CWRC) at varying percentage of water is established by using chilled mirror dew point method. Furthermore, a comparison on the resistivity of activated carbon and pyrolytic carbon is tested at varying percent of water content is carried out by using chilled-mirror dew-point method.

1.5 Significance of research

The use of activated carbon and pyrolytic carbon maybe useful for improving earth grounding resistance in trouble environment.

1.6 Thesis Overview

This thesis consists of five-consequence chapters.

Chapter 2 presents the overview of other research that related to the earth grounding system, activated carbon, pyrolytic carbon and soil-water retention curve (SWRC) that also related with the carbon water retention curve (CWRC). Earth grounding system is explained on its significant, factor that influence the performance of

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