INVESTIGATION ON ELECTRICALLY CONDUCTIVE GROUNDING MATERIALS PRODUCED BY INCORPORATING GRAPHITE AND MARCONITE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor Degree of Civil Engineering (Hons.).

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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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ABSTRAK

Pembumian adalah istilah yang ditakrifkan sebagai sambungan konduktor atau bingkai peranti ke jisim bumi. Tujuannya adalah untuk menyuraikan aliran caj ke bumi dalam masa yang singkat sekiranya berlaku sambaran kilat dan memastikan operasi grid kuasa dan aksesori elektrik yang stabil. Rintangan bumi ini bergantung pada susunan elektrod dan juga kerintangan tanah sekitarnya. Dalam kajian ini, bahan berasaskan karbon iaitu grafit dan Marconite digunakan sebagai bahan peningkatan tanah untuk meningkatkan prestasi sistem pembumian. Kajian ini bertujuan untuk menentukan sifat-sifat fizikal dan ciri-ciri geoteknikal, membina keberintangan pengekalan air karbon (CWRC) pada peratusan kandungan air yang berbeza-beza serta mengukur kerintangan elektrik, penyerapan air dan kekuatan penghancuran bahan-bahan konduktif elektrik. Bahan-bahan ini diuji dalam bentuk serbuk dan batuan. CWRC ditubuhkan dengan menggunakan WP4C Potentia Meter dan rintangan elektrik dibaca menggunakan kaedah kotak tanah. Pada hari 28, agregat dengan 1.0% jisim grafit mempamerkan 49.2 Ω.m rintangan elektrik, 12.61% penyerapan air dan 7.45 N/mm^2 kekuatan bahan. Berbanding dengan Marconite, agregat dengan 1% Marconite memiliki 39.2 Ω.m resistivitas elektrik, 12.93% penyerapan air dan 11.11 N/mm^2 kekuatan bahan. Keputusan menunjukkan bahawa kedua-dua bahan boleh diganti sebagai bahan peningkatan tanah. Walau bagaimanapun, Marconite adalah alternatif yang terbaik untuk digunakan kerana memberikan nilai rintangan yang lebih rendah, kurang sedutan tanah, kekuatan penghancuran yang lebih tinggi dan penyerapan air yang lebih tinggi pada hari ke 28 berbanding dengan grafit.

ABSTRACT

The term earthing is defined as the connection of a conductor or frame of a device to the general mass of earth. The purpose is to disperse flow of charge to mother earth within the shortest time at the event of lightning and to ensure stable operation of power grid and electric accessory. This earth resistance depends on electrode arrangements as well as the surrounding soil resistivity. In this study, carbon-based material, namely graphite and Marconite were used as ground enhancement materials to improve the performance of earth grounding system. The study aims to determine the physical properties, establish carbon water retention curve (CWRC) at varying percentage of water content as well as to measure the electrical resistivity, water absorption and crushing strength of electrically conductive grounding materials. These materials were tested under powder and aggregated form. The CWRC was establish by using WP4C Potentia Meter and electrical resistivity were read using soil box method. At days 28, the aggregate with 1% by mass of graphite exhibited 49.2 Ω.m electrical resistivity, 12.61% water absorption and 7.45 N/mm² crushing strength. Comparing to Marconite, the aggregates with 1% Marconite possessed 39.2 Ω.m electrical resistivity, 12.93% water absorption and 11.11 N/mm² crushing strength. Results revealed that both material can be replaced as ground enhancement materials. However, Marconite is the best material to be use as an alternative grounding material due to having lower resistivity value, higher crushing strength and higher water absorption at days 28 compared to graphite.

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LIST OF SYMBOLS

Ω.m	Ohm meter
Gs	Specific gravity
WA_{24h}	Water absorption
F	Crushing strength
%	Percentage
Cu	Uniformity coefficient
Cc	Coefficient of gradation
μm	Micron meter

LIST OF ABBREVIATIONS

GEM	Ground Enhancement Materials
IEEE	Institute of Electrical and Electronics Engineers
CWRC	Carbon Water Retention Curve
GEM	Ground Enhancement Material
BET	Brunauer-Emmett-Teller
CEC	Cation Exchange Capacity
SWRC	Soil-water Retention Curve

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The term earthing is defined as the connection of a conductor or frame of a device to the general mass of earth (Eduful *et al*., 2009). Earth protection system, also known as grounding system, is to protect the equipment in the substation by providing low impedance path for the fault current to flow to the earth (Loo and Ukil, 2017). In an electrical power system, the integrity of the grounding system is very important to maintain a reference point of potential for equipment and personnel safety, to provide a discharge point for lightning currents as well as to prevent excessive high voltages on the power system (Khan *et al.*, 2011). This ensures that any individual in the vicinity of the grounding system is not exposed to a critical electrical shock (Jasni *et al.*, 2010).

In the power system, the grounding electrode is buried in the soil, which is used for the overflowing of the ground current, to ensure secure and stable operation of power grid and electric accessory. The buried depth of the grounding electrode is generally 0.3~0.8 m (Liu *et al.*, 2017). This earth resistance depends on electrode arrangements as well as the surrounding soil resistivity. When the surrounding soil has very high resistivity, multiple parallel rods have to be used where the spacing between rods must be at least twice the rod depth. However, when the soil resistivity is either too high or the space is insufficient to construct the grounding network of required number of parallel grounding rods, low ground resistance values are required and typical values are usually specified by utilities for different situations (Khan *et al.*, 2010; Khan *et al.*, 2011).

Soil resistivity is one of the major factors that determine the effective performance of a grounding system. By ensuring low soil resistivity for a grounding system, its performance can be greatly enhanced. Different soils have different grounding resistivity, it is advisable therefore to always consider soil resistivity variations while designing for grounding systems (Amadi, 2017). In many of the applications of earthing, low earth resistance is essential to meet electrical safety standards. However, in certain soils, it has been extremely difficult to obtain and maintain a satisfactory earth resistance values. As a means of reducing the earth resistance, a chemical treatment and other widely used methods (Eduful *et al*., 2009).

The earth enhancement materials such as bentonite and Marconite conductive concrete as a backfill for earthing are widely used (Androvitsaneas *et al*., 2012; Tshubwana *et al*., 2016). Marconite have extremely low resistivity of 0.001 Ωm at its initial state, while bentonite demonstrates extremely lower resistivity in the wet condition (Gomesa *et al.*, 2010). Generally, soil suction refer to the ability of soil to attract and hold water. It has been acknowledged that the soil suction and water content are essential parameters that governs various properties of unsaturated soils (Nam *et al*., 2010). The wet condition in return depicts high water content which is the main factors that contribute to soil corrosion (Lim *et al.*, 2013).

The carbon fibre-carbon black composite electrically conductive concrete was employed as new grounding material, which has good grounding performance (Zhang *et al*., 2017). Electrically conductive concrete is a category of concrete containing electrically conductive components to attain stable and high electrical conductivity (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).

In this study, graphite and Marconite were used as ground enhancement materials. Similarly, the materials was mixed with Ordinary Portland Cement (OPC) as conductive aggregates. Several test were conducted such as water content, particle size distribution, specific gravity and BET surface area. Carbon water retention curve (CWRC) was established to determine the improvement of carbon-based at varying percentage of water content. Lastly, electrical resistivity, water absorption and crushing strength were determined in aggregated form.

1.2 Problem Statements

Desired grounding resistance can be achieved by connecting a number of individual electrodes instead of using single low grounding resistance electrodes (IEEE Std. 142, 2007). However, it is very difficult to get the expected grounding resistance by increasing the grid conductor as it is costly. As the resistivity value and properties of the soil were different depending on the different site location, the stable soil resistant are not easy to achieve, thus, it is more convenient to replace or improve the unstable grounding by using new developed materials to obtain 1.0 Ω.m resistivity value.

Carbon based materials such as graphite and Marconite to be replace as electrically conductive grounding materials may be used to improve the resistivity of soil in trouble environment.

1.3 Objectives

The objectives of this study are:

1. to determine the physical properties of graphite and Marconite.
2. to establish carbon water retention curve (CWRC) of graphite and Marconite at varying percentage of water content.
3. to measure the electrical resistivity, water absorption and crushing strength of graphite and Marconite.

1.4 Scope of study

In this study, two carbon based materials which are graphite and Marconite were used. Laboratory investigation was carried out to determine the properties and characteristics of the raw materials in powdery form. Later, the resistivity of raw materials is investigated and compared with the resistivity in aggregated form mixed with ordinary Portland cement (OPC). OPC and sand mixed with 1% graphite and OPC and sand mixed with 1% Marconite were considered. Test were conducted in the period of 7, 14 and 28 days of curing. Water absorption and crushing strength of this materials is also investigate. Carbon water retention curve (CWRC) of graphite and Marconite at varying water content was establish by using chilled-mirror dew-point method and PotentiaMeter.

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