Preliminary result on the enhancement of Ufer electrodes using recycle additives materials

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Abstract. Ground building pillars is to be used as ground rod. The pillars are design, fabricated, and formulated with new ground fillers. The additives will be used from recycle waste materials mainly from the palm oil plant process. Micro scale building pillars will be fabricated and install in the test ground at all of the location. Earth tester meter are used to measure and collect the data of the soil resistivity when the research is conducted. In collecting these data, 3-terminal methods are used to carry the measurements. This experiment will be conducted for 30 weeks and regular measurements at the test ground copper grids will be conducted to measure the ground electrode resistance. The study will mainly base on IEC 62503-3. The used of reinforcing rods and mixture of recycle additives could produce a better grounding system that are suitable and can be used in all kind of soil condition and large industries.

1. Introduction
The first use of concrete encased electrodes is probably reported by Herb Ufer at a bomb storage facility at Darvis-Monthan AFB in Tucson, Arizona which he inspected early in World War II. The grounding system was to protect against both static electricity and lightning. He later reinspected the installation and made further tests, proving that concrete-encased electrodes provide a lower and more consistent resistance than driven ground rods, especially in arid regions. Due to this early usage, the use of a wire or rod in the concrete foundation of a structure is often referred to as a “Ufer ground.” [1]

The findings of Ufer [2] that metal encased in concrete performs as an effective grounding electrode, constitutes a major breakthrough in grounding technology. This has been recognized to the extent that copper wire embedded in the concrete footings of a structure is now an acceptable alternative to driven rods or pipe electrodes in the soil. [3]

Under unfavorable conditions of the soil, the concrete encased metal objects contributed in the effectiveness of improved grounding. It was suggested that the reinforced footings framework in the structure of columns of steel buildings yield effective grounding function. Results of the tests in high, medium and low resistivity soils showed that the grounding capability with strong footings is identical to low and medium soil resistivity of conventional electrodes. On the other hand, it is superior in comparison to conventional electrodes of high resistivity soil conditions.
In areas where driven rods are unlikely to be effective, the Ufer grounding system is outstanding for low fault currents application. For example, in residential or commercial areas where the driven rods are considered to be less effective. It is crucial in terms of the system design to consider the high current faults such as lightning. It was found that isolating the foundations from the other parts of the grounding system is impossible. Concrete is able to absorb moisture from its surrounding earth which assists in reducing the resistance. In arid situations however, physical damage may occur to the concrete due to its non-homogeneous properties and moisture content. In the event of a fault, a path from the rebar to the surrounding soil through the concrete will have a lower resistance than any other. In addition, water heating and vaporization occurs when fault currents flow through the path thus causing the concrete to crack or spill. [1]

2. Literature Review

In order to protect against static electricity and lightning, Ufer grounding system was built. It was proven that in arid areas, the concrete-encased electrodes gave a lower and much consistent resistance than the driven ground rods. Dick and Holiday (1977), discussed and approved that the previous test on concrete-encased electrodes provide low resistance ground before and after high current faults. In addition, it was found that with very high fault current between 500 to 2600 amperes occurring over a long period of time would cause either minor damage or thorough destruction to the concrete.

A survey carried out in 1975 found that 90 fractured foundations were grounded using Ufer method out of a total of 1414 transmission towers. Lightning strikes to the static wires were considered as the cause of the fractures. Several factors caused the disintegration of concrete. Firstly, due to the leakage current. It exists when metallic path disruption occurs within the current path in the concrete. Secondly, in the case where there was no connection between the anchor bolts and the rebar cage in the foundation.

IEEE Std 80 (1986) substation ground guide, discussed the pros and cons of Ufer grounding and indicated that isolation of rebar from the grounding system is impossible. In comparison to the ground rod, the Ufer grounding system has a lower resistance, achieved by having larger diameter and cross section of concrete. The concrete is able to absorb moisture in the surrounding earth, even in dry areas, in order to reduce the resistance. [1]

The requirement for the system is to use rebars that are either bare or have zinc coating. Usually these are the minimum standards that are applied to a rebar that being used as an earthing electrode: [4]

- Minimum length of 6m
- Minimum diameter 13mm

And installed:

- In a minimum of 55mm of concrete
- Concrete is in direct contact with earth
- Located within and near the bottom of a concrete foundation or footing
- Permitted to be bonded together by the use of steel tie wire

Conversely, for good continuity of rebars, steel tie wire is unsuitable. Joining products particularly for the rebars are available in the market. An appropriate connection of the rebar ensures low resistance path to earth for lightning and earth current faults.

2.1. Used of concrete-encased reinforcing rods as grounding electrodes
According to Eugene J. Fagan and Ralph H. Lee members of IEEE, they had recorded the effectiveness of primary electrodes in a footing pedestal. A good correspondence of measured footing resistance and calculated grounding resistance of ¾ inch diameter rod were recorded. In contrary, at
the lowest resistivity of soil, a 10-foot and 5-foot rod shows approximately the same grounding resistance in average soils. It is crucial that equivalent depths have to obtain equivalent resistance in highly conductive soil. The surrounding of a metallic bar with concrete in the earth constitutes immersion of the bar in a reasonably uniform medium about 3000 Ω·cm. The resistivity of this medium varies from minimum about 500 Ω·cm to over 500000 Ω·cm when immersed in the earth. The surface area of rod and the outer surface of concrete are compared in terms of the material’s resistivity. In addition, it controls the net ground circuit resistance, where the calculations and record are made by Eugene J. Fagan and Ralph H. Lee [5]. The effectiveness of concrete as a uniform resistivity “ground” is due to its inherent alkaline composition and hygroscopic nature. As described by Ufer, [2] moisture from the soil is drawn by the concrete to keep a higher water content for accounting consistent and low resistivity, even under the dessert condition. Based on the result obtain from their test and those earlier work, they had concluded that the reinforcement of concrete footings have a tolerably low grounding resistance. The fault and surge current capability was determined to fit multiple structures and circuit grounding. Apart from that, the rebar system has the least advantages in terms of readiness or availability and low costing.

2.2. Used of backfills materials
In high resistive soil, a common method to achieve low earth resistance is to cover the electrodes with conductivity material also known as backfill materials. The backfill material has the benefit of generating good earth resistance in space-restricted areas with extremely high soil resistivity. Low frequency resistance of several backfill materials were tested in the past years [7-9]. Specifically, several studies related to the properties of backfill material were carried out. The findings were inclined to prevent or reduce corrosion for the system. In addition, tests were carried out to determine the suitability of bentonite mixed reinforced concrete as earth electrode to overcome the disadvantage of backfill materials. Based on long-term professional experience and outcome of a previous study, bentonite has been selected as the mixing substances with concrete. [7] The study aims to identify the most suitable concrete mix for standalone earthing electrodes and making multipurpose building foundations. The investigations are conducted based on following parameters: [10]

- Long term variation of low frequency resistance
- Most effective proportion of bentonite in the concrete mix
- Resistivity and permittivity
- Impedance characteristic under impulse conditions
- Mechanical stress withstanding capacities
- Corrosion resistance/promotion of the concrete mix

Investigation of the earth resistance of buried steel cages, encased in bentonite mixed concrete was carried out. A reference pit was constructed with steel cage encasing in ordinary concrete. The site has uniform surface soil resistivity within the range of 100Ωm. Over a period of five months, measurements of each of the electrodes performance were made. [10] In the earlier phase, the lowest earth resistance and the highest decrement in earth resistance were shown by the pit with concrete having 20% bentonite. However, in the subsequent four months, pits with bentonite mixed concrete showed increased earth resistance compared to the reference pit. As a result of the research, it is affirmed that concrete blocks has the capability of sustaining the earth resistivity with rather low fluctuation apart from the pits with 20% and 70% bentonite. Two major outcomes are drawn. Firstly, bentonite is identified as the backfill material due to its incapability to be mixed with cements, gravel and sands in making the concrete mixture. Secondly is the reconfirmation of the earth resistance-fluctuation-minimizing effect of concrete. Finally, to conclude the performance of the newly introduced material, the experiment has to be carried out repeatedly at varying soil resistivity sites for a period of at least several years.
3. Methodology
Initially, the project was started by combining the idea of those researches and produce a new enhancement of Ufer electrodes by using recycle additive materials. The used of reinforcing rods and mixture of recycle additives could produce a better grounding system that are suitable and can be used in all kind of soil condition and large industries.

3.1. Planning
In order to produce an improve and good system, the experiment should be conducted at sites with different condition with various soil resistivity ranging from moderate values such as few hundred Ohms to very high values such as few tens of kilo Ohms. [10]
So, three different locations had been selected which are:

- Research Centre for Soft Soils (RECESS)
- Sandy beach located in Pantai Minyak Beku area.
- Upper hill where the soil is dry at Gunung Soga

These site has different conditions of soils which is considered suitable to conduct the experiment so that the effects of the improve system on these soil condition could be supervised and investigated.

3.2. Designing
SOLIDWORK EXPLORER 2014 software is used to draw a proper design of the pillars before it being constructed. The design of the pillars from the software is shown in Figure 1 and the measurements of the pillar are recorded in Table 1:

|                   | BASE  | COLUMN (feet) |
|-------------------|-------|---------------|
| LENGTH            | 1.5 feet | 1 feet        |
| WIDTH             | 1.5 feet | 1 feet        |
| HEIGHT            | 5 inches | 1 feet        |
3.3. Testing
A Sher strength test will be conducted in order to know the strength of the concrete and the new additive strength when it is combined with the concrete. If the strength of the new mixture is stronger or the same as the concrete, the experiment will be continued by fabricating it into the pillars. During this step, it is important that the mixture is being left for 28 days before the Sher test is conducted.

3.4. Fabricating
Reinforced steel bars are used as the core structure of the pillars. Firstly, the base of the pillars is structured according to the final design and twisted-steel tie wires were used to hold them together. (Figure 2) Subsequently, the pillar column was constructed from the spread footings upward through the foundation and positioned by horizontal steel bars loops at fixed gaps. [5] For an effective electrical connection, twisted-steel tie wires were used to secure them together. Electrical connection was made by welding a short bar between the anchor bolt and the vertical rebars. The anchor bolts are only connected to the column. The edge of which is a concrete footing, having a common resistance value of 50Ω for each column. Thus, it is said to have reasonably low resistance. Furthermore, there is no footing damage since the surge has a safe conduction to earth. [5] The based and column of the rebars are connected together performing a core structure of the pillars. (Figure 3)
After finished structuring all the rebars, the wooden planks are designed and used to hold the concrete together as the formwork. Then, a stranded copper wire coil is laid in just before the concrete mixture is poured in the structure. The mixture ratio of the cement is (1 part Cement: 1.5 parts Sand: 3 parts Aggregate with 0.5 parts water volume). Basically 9 pillars are built as three of different pillars with three different mixtures will be installed at each site. The difference between them is only the cement part of the ratio. The 1st pillar ratio is exactly as the stated ratio above while the other two types of pillars consists of half pillars and half recycle additives materials. After the concrete has set the wood may be removed.

3.5. Analysing
After all of the pillars already being installed at all of the locations, the resistance readings will be collected every week. The equipment that will be used throughout this experiment is the earth tester meter to measure the soil resistivity where the 3-terminal methods are used to carry out the measurements. In this paper we present the preliminary result of the ongoing research.
4. Preliminary result and discussion

Research had been conducted on the previous work of Ufer [2] electrodes system and a conclusion had been deduced in order to improve the system. After taking into consideration of all the pros and cons on the conducted studies, it seems that the Ufer grounding system could be enhanced by using recycle additive materials. In this research, the additives will be used from recycle waste materials mainly from the palm oil plant process. It supposed to act by giving a low resistance reading other than increasing the strength of the concrete in order for the system to be used for a longer period of time and support the fault current that flows through it during high fault condition.

It was found that the Ufer [2] method with reinforced framework of footing columns was effective in improving the grounding function even in unfavorable soil conditions. The grounding capability was tested through high, medium and low resistivity soils. Results of the tests in high, medium and low resistivity soils showed that the grounding capability with strong footings is identical to low and medium soil resistivity of conventional electrodes. On the other hand, it is superior in comparison to conventional electrodes of high resistivity soil conditions.

Weiner [6] proved that concrete-encased metal rods had an extensive ground current capability. The corrosion rate is lower compared to the rods directly in the earth.
In the concrete footings of structural steel and concrete buildings, there is an untapped reservoir of grounding electrodes that already installed or being installed. This is the reinforcing steel network within each of those footings, made up principally of vertical rods in the pedestals and horizontal rods in the spread footings at their bases. Cross members are utilized for separation and stabilization.

A good method of attaining an electrode system with low resistivity is provided by concrete foundation placed underground. In comparison to common rods which are directly buried into the ground, a much lower resistivity of approximately 30Ω at 20°C can be achieved when using a rod placed and encased within concrete. Steel reinforced concrete are common materials used in the construction of buildings. Thus, the is a possibility that the electrode conductor is the reinforced rod. This can be done in every individual foundation to ensure a proper electrical connection to the main rebar. [4]

The estimation value of grounding resistance of column footing electrodes is calculated based on the following approximations: [5]

- Effectively, four reinforcing bars of ¾ inch diameter are near the corners of the footing pedestal. While possibly only one bar is directly connected to the system to be grounded, the other three are connected by multiple horizontal rib bars and tie wires.
- The effective concrete layer around each bar is a ¾ cylinder (270°) of radius 2 inches from the bar surface.
- Considering the spread footing base is as merely a linear extension of the pedestal, the size is neglected. Consider the electrode have length equal to the buried total depth of the footing.
- The resistivity of the soil is uniform from top to the bottom of pedestal (below earth surface). Effectively, a value for resistivity at 2/3 of the depth may be used, or a value determined by measurement, using test electrode spacing equal to the height of the pedestals.

Based on some of the previous study on grounding electrodes, it shows that the use of concrete-encased reinforcing rods as grounding electrodes provides effective grounding function and mean. The factors that marks the desirability of the rebar type compared to the existing system is because it is cheaper more suitable and widely available in the market. However, concrete has a non-homogeneous character which makes the concrete possible to be damage. During a fault, one path from rebar outside soil through the concrete will have the lower resistance than any other. In the event of a fault, a path from the rebar to the surrounding soil through the concrete will have a lower resistance than any other. In addition, water heating and vaporization occurs when fault currents flow through the path thus causing the concrete to crack or spill.

Alternatively, to overcome the problem of concrete corrosion in the system, the performance of the grounding electrodes encased in bentonite mixed concrete was studied to aim for prevention and reduction of corrosion. Bentonite is determined to have the capability to be mixed with cements, gravel and sand, thus having the properties of soil conductance enhancement material. The experiment has to be carried out repetitively on various resistivity of soil to ensure the performance of the introduced material for duration of over a few years.

After researching and studying on these systems, it would be great to combine the idea of those researches and produce a new enhancement of Ufer electrodes by using recycle additive materials. The value of the resistance is expected to be within range of 0Ω – 25Ω in order to become a better grounding system.

5. Conclusion
At the end of this study, observation will be done based on how recycle additive material could enhance Ufer electrode as ground system and lastly, developing a stronger ground building pillars that is could be used as ground rod in Ufer grounding system. For future research regarding the grounding resistance reducing agents, the results of this research is evidently favorable and crucial. The use of
reinforcing rods and mixture of recycle additives could produce a better grounding system that are suitable and can be used in all kind of soil condition and large industries.

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