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MAPPING OF SOIL CORROSION OF NEAR-SUBSURFACE USING RESISTIVITY METHOD IN BANDA ACEH AND ITS SURROUNDING AREAS

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ABSTRACT

The stiffness of foundation structures must periodically be concerned. This is very crucial to building itself. To obtain this information, the corrosion degree of near-surface soil can be investigated. This research was performed in Banda areas and its surrounding and aims to delineate the soil corrosion degree. Achieving this goal, resistivity method and pH measurement were carried out in the 14 areas consisting of Baet, Miruk Taman, Cot Iri, Lambhuk, Ulee Lheue, Punge, Deah Baro, Blang Bintang, Batoh, Lamjamee, Peukan Bada, and Lam Ateuk. For the resistivity data acquisition, the Wenner 4-pin of ASTM-G57 was applied to provide soil resistivity values processed by utilizing the Res2Div software. While the pH values were probed by using the pH meter. Both data are an in-situ measurement. The processed resistivity data and pH values are combined for each area. The result shows that there are two locations predicted as the very corrosive soil which is Lamjamee and Lam Ateuk whose the resistivity and pH value of 2-6 Ωm, pH ≤ 5 and 12-20 Ωm, pH ≤ 6.31 respectively. The following types of soil are susceptible to be corrosion including Lambuk, Ulee Lheue, Punge, Batoh, Peukan Bada, and Lambaro. These potentially corrosive soils are probably influenced by moderately watered content and their pH values are normal but tend gradually to be decline by the time. The last category is non-corrosive soils existed in such areas of Miruek Taman, Deah Baro, Blang Bintang, and Lampeunerut. The whole types of soil corrosion degree are displayed on the map from which views an integral part of soil corrosive characterization.

KEYWORDS: foundation; soil-corrosion; resistivity-Wenner 4-pin-pH.

INTRODUCTION

Intensively built of infrastructure in term of building necessity for settlement is exactly unavoided because of population growth. This will consequently need to the friendly examinated areas where their subsurface information geotechnically could be recommended to become the save areas for living. One of the potentially problems of near subsurface ground is corrosive soils affecting to material foundation that composes of possibly corrosive materials such as iron, steel, etc. This potentially corrosive material of foundation would gradually endanger building itself.

The corrosive soils are simply controlled by the degree of soil acidity and soil salinity. Banda Aceh city and its surrounding are moderately potential having the corrosive soils. This is because its geography exists near to coastal zones where part of them dominantly flooded by the unforgetable tsunami in 2004. The enundation of tsunami transported the sea sediments and were deposited within subsurface in which the salinity has been probably remained. The degree of soil salinity could be identified by geophysical method which is effectively using geo-electrical method. The corrosive material foundation is an hazardous geology which is exactly unseen on the surface. It will gradually destruct the quality of building foundation and as the common knowlegde the Banda Aceh are prone to earthquake, so that the foundation materials must be regularly monitored. Otherwise, it would highly collapse building itself and threat human life.

In addition to this, a mapping of corrosive soils degree must be conducted. This map could be used to analyze disaster risk of infrastructure demage.

The develoved countries such as United State and Eroupean countries have applied the building permit. Prior to build infrastructure, eximination of corrosive soil degree must initially be done. A similar rule must be applied in Indonesia and spesifically in Aceh because Aceh province is susceptible to the earthquake disaster. In order to the view, this reserach is very crucial to be implemented.

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Several factors influencing soil corrosion are reduction and oxidation prosess, resistivity, solved ion, pH, water content. However, soil resistivity is the main factor highly related to subsurface soil corrosion. Willmott, *et al.* (2006) stated that if soil resistivity tends to be low, the degree of soil corrosion experiencing on burial metal would be high. At another view Paillet, *et* al. (2010) expressed many factors are correlated to soil resistivity parameters such as salinity, water content, texture of sand, clay and its depth below subsurface. So that soil resistivity is represented to several properties of soil corrosion. As an underlined thought that the soil reisitivity is a comprehensive parameter to soil corrosion (Corwin, *et al.* 2003).

Resistivity parameter measurement was carried out by injection electrical current into the ground and then its response, as a potential different, was probed from two electrodes. Other than that, the degree of hydrogen potential (pH) was also directly measured in the area (*in-situ*). This pH measurement is an additional parameter combined to soil resistivity values to generate soil corrosion map.

LITERATURE REVIEW

GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

The study area is mainly located in the area of Banda Aceh as the capital city of Aceh province having 61,36 kilometer squares. Geographically, Banda Aceh is existed at the latitude 05º30′59,00’’ – 05º36′ 45,40’’ and longitude 95º16′25,49” – 95º22′40.00”. Administratively, Banda Aceh consists of nine subdistricts which are Meuraxa, Baiturrahman, Kuta Alam, Syiah Kuala, Ulee Kareng, Banda Raya, Kuta Raja, Lueng Bata, and Jaya Baru.

The topography of Banda Aceh is around of interval -0.45-1.00 meter above mean sea level (msl) with the average height 0.80 meter. Based on its topography, Banda Aceh and its surrounding are flooded area of the Krueng Aceh and 75 % of its area exsists at less than 5 meters of above mean sea level. (RPJM Kota Banda Aceh 2012-2019).

According to the geological map of Banda Aceh, the study area is an alluvial sediment (Qh) composing of loose materials as example, clay, silt, sandy gravel and boulder (Bennett *et al*, 1981) that shown in Fig 1 below:

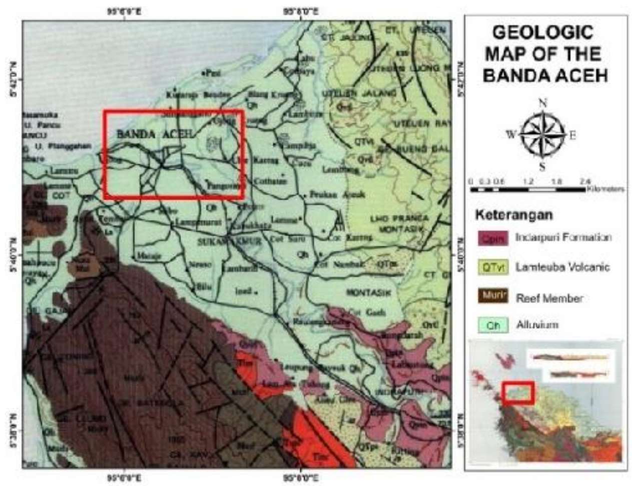

Fig 1. The geological map of Banda Aceh (Bennet *et al*, 1981).

Resistivity Parameter

The corrosion is the decline of quality of metals caused by happening of chemical reaction to environment. Resistivity parameter has been utilized as the main indicator for examining of soil corrosion level (Willmott, *et.al*, 2006).

The Wenner whose a standarized method used to assess soil corrosion has been applied. This method has been patented by *American Society for Testing and Materials* with serial ASTM-G57. The Wenner 4-pin configuration uses 4 electrodes planted on the ground at the straight line by placing electrodes at the same distance (spacing). The principal procedure of the Wenner 4-pin resistiviy is pictured by Fig 2 below :

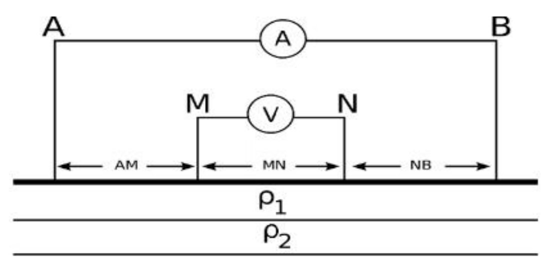

Fig 2. The Configuration of ASTM-G57 Wenner 4-pin for soil resistivity measurement.

The position of two electrodes which are A and B connected to DC electrical current and positioned inline with ampermeter, while the electrodes of M and N are the potential electrodes linked to voltmeter at which changing of potential from the M-N electrodes is measured. This reading of potential different is converted to resistivity value (Corwin, *et al.* 2003).

The result of measurement resistivity value is the appearent resistivity generally representing subsurface

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soil. This appearent resistivity must be processed to the true resistivity expressing the highly probable information of subsurface. To obtain this intention, the *Barnes Layers* (ASTM-G57) were used.

The classification of resistivity value showing the degree of soil corrosion is summarized in Table 1. The approximate value of resistivity is issued by *American Water Works Association (AWWA).*

Tabel 1. The relation of resistivity value versus the degree of soil corrosion

Soil Resistivity (t cm)	Degree of Corrosion
>20.000	Non-corrosive
10.000 – 20.000	Slightly corrosive
5.000 – 10.000	Moderate corrosive
3.000 – 5.000	Corrosive
1.000 – 3.000	Very corrosive
< 1.000	Extremely corrosive

Source: *American Water Works Association (AWWA), 2014*

Parameter of pH

The indicator of corrosion level occuring on buried metal other than is revealed by soil resistivity, but also can be observed through the degree of acidity and alkalinity of water soluble substances (pH).

The relation between environment and the level of soil acidity and alkalinity affect the corrosion process. The soil acidity is originated from carbon dioxide resulted of biology and water. The pH value is shown in Table 2 below :

Tabel 2. The degree of soil corrosion based on the pH value

pH value	Degree of corrosion
< 5	Very corrosive
5-6	Moderate corrosive
7	Normal
7-10	Non-corrosive

Source: *National Assosional of corrosion enginers*

RESEARCH METHODOLOGY

This reserach was divided into two stages which are data acquisition (*field work*) and data processsing at laboratory. Data acquisition consists of resistivity and pH measurement of fourteen (14) points in research area as seen in Fig 3. While the data processing was done at the Near-Surface Goephysics Laboratory of Geophysical Engineering Department of Syiah Kuala University. The distribution of 14 points were existed 10 points in Banda Aceh areas and 4 points in Aceh Besar subdistrict.

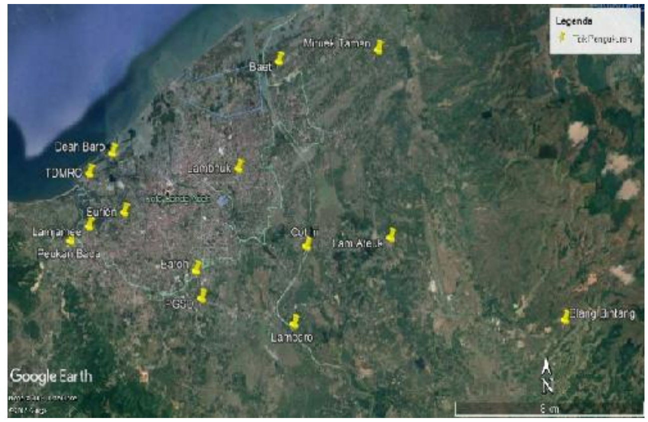

Fig 3. The distribution of 14 points measurement

The Wenner 4-pin was applied by using Super Sting made in *Advanced Geoscience*. While the pH measurement was measured in-situ by utilizing the pH meter. Both data measuerement were combined to produce the map representing the soil corrosion degree.

RESULT AND DISCUSSION

The resistivity and pH values of the research are summarized in table 3 below :

Tabel 3. Resistivity, pH values and soil corrosion degree

No	Location	Resistivity values (t m)	pH	Corrosion degree
1	Baet	0.5-3	7.73	Potentially Corrosive
2	Miruk Taman	41-175	7.36	Non-corrosive
3	Cot Iri	5-14	7.22	Potentially Corrosive
4	Lambhuk	9-17	6.98	Potentially Corrosive
5	Ulee Lheue	1-25	7.15	Potentially Corrosive
6	Punge	7-33	6.98	Potentially Corrosive
7	Deah Baro	9-203	7.36	Non-corrosive
8	Blang Bintang	24-70	6.20	Non-corrosive
9	Batoh	5-6	7.92	Potentially Corrosive
10	Lamjamee	2-6	5.08	Very Corrosive

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11	Peukan Bada	15-23	7.28	Potentially Corrosive
12	Lam Ateuk	12-20	6.31	Very Corrosive
13	Lambaro	6-8	7.63	Potentially Corrosive
14	Lampenerut	5-13	7.63	Non-corrosive

Resistivity values of rocks generally depend on the physical parameters which are porosity, salanity, temperature and termal change. An increase of these parameters will decrease the resistivity values of rokcs (Telford, W. M. 1990). The relation between resistivity and pH value are inline inferring that if resistivity of rocks is low which is possibly an existing of water content, so that the pH value tends to be low where its degree is pointed out in Table 2.

According to 14 points measurement whose 20 meters spread length of each in different areas were tabulated in Table 3 above.

It can be seen that there are existed two locations that are predicted the very corrosive soil. These locations are Lamjamee and Lam Ateuk. They have the resistivity and pH value which are 2-6 Ωm, pH ≤ 5 and 12-20 Ωm, pH ≤ 6.31 successively. Geographically, Lamjamee is close to coastal area and was flooded by the 2004 tsunami. This may cause the location very corrosive. The higher degree of corrosive soil may probably originate from tsunami sediment deposit. In the other hand, Lam Ateuk is far away from coastal area, but it is close to small water channel by which the investigated soil has undergone to be corrosive because of highly water content indicated by very low resistivity value.

The other locations are classified into potentially corrosive soil such as Baet, Cot Iri, Lambuk, Ulee Lheue, Punge, Batoh, Peukan Bada and Lambaro. Their resisvity and pH values are pointed out in Table 3. Based on their resistivity value, the areas which are potentially corrosive caused by high water content within near surface soil. This water content is simply existed in porous soil. While their pH values are plus- minus in normal range.

Addtional information from these potentially corrosive areas is that the areas of Baet, Ulee Lheue, Punge and Peukan Bada include in coatal areas where the 2004 tsunami surged. These potentially corrosive soils in the areas were approximately produced by sediment transport of tsunami.

The another classification of soil corrosion which is non-corrosive soil consists of Miruek Taman, Deah Baro, Blang Bintang and Lampeunerut because they have the resistivity values larger than other areas indicating the areas are not highly water content and their pH values aslo above 7. However, the pH value of Blang Bintang is lower than 7 which is 6.20. The low value is possibly caused by leachate of landfill because of the measurement point is around 50 meters from landfill.

Furthermore, all of the soil corrosion classifications are plotted by using Surfer intending to view them integrally. This plot of view is shown as in Fig 4. below :

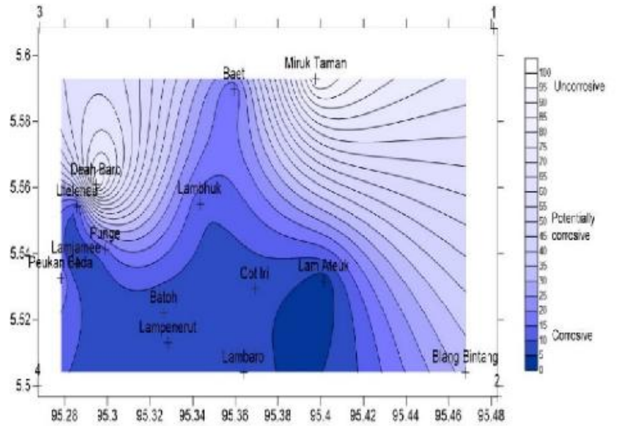

Fig 4. Map of soil corrosion degree of 14 measurement points

CONCLUSION

Refferencing to the result and discussion, it could be concluded that there are three classifications of 14 measurement points of soil corrosion degree. Firstly, the hingest degree of soil corrosion is existed in the areas of Lamjamee and Lam Ateuk. Secondly, the moderate or potentially occured soil corrosion is Baet, Ulee Lheue, Punge, Peukan Bada and Lambaro. Lastly, the non-corrosive soil is deliniated in the areas of Miruek Taman, Deah Baro, Blang Bintang and Lampeunerut.

These results of soil corrosion degree based on characterization should be advanced to carry out more measurement points in each area. This is intended to validate or combine the result, so that the finding would be more reliable.

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