Evaluation of Corrosion of Geothermal Power Generation Utilization of Reinforced Concrete Structure

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Abstract
Geothermal power produces electricity as an energy source for the earth's internal heat. The temperature in the ground, close to the earth's surface, is kept at around 10~20℃. With these characteristics, it is possible to build a heating and cooling system using a heat pump. The heat exchange with the ground is carried out through a heat exchanger, in which the refrigerant acts as a medium for heat transfer. Generally, the heat exchanger is completed by drilling a hole of 100 meters, inserting a U-shaped tube, and filling the space between the tube and the hole with grouting material. On the other hand, reinforced concrete has many advantages such as high strength expression, economy due to low cost, and long service life, so it is the most widely used construction material worldwide. Recently, due to the price increase of steel materials and the increase in logistics costs, the total construction cost has doubled. In this study, pipe rebar was developed to reduce steel materials, and since it is a pipe rebar that increases the strength of the material, there is no problem in terms of strength, but since corrosion resistance has not been reviewed, the corrosion resistance was evaluated in various corrosive environments to use pipe rebar as geothermal power generation. As a result of the experiment, it is judged that pipe rebar can be used as an alternative to the general rebar used in existing buildings. In addition, it is found that pipe rebar can be used as a geothermal heat exchanger piping.

Index Terms— Geothermal power, Corrosion, Reinforced concrete, Refrigerant, Heat exchanger

I. INTRODUCTION

Reinforced concrete is the most important material in modern construction technology such as large buildings and civil structures. Compressive-resistant concrete and tension-resistant rebar are excellent construction materials that overcome each other's shortcomings. Recently, due to diplomatic frictions such as situation in Ukraine, there has been a problem of disruption in the supply and demand of raw materials, and the price of raw materials has skyrocketed. Increase in rebar prices due to reduced production due to the abolition of the 13% export refund tax rate. As the production of rebar decreased, the material price of reinforced concrete increased, creating a deficit in construction.

There are two reasons for exporting countries policy: the first is carbon emission reduction, and the second is disruption in the supply and demand of raw materials (iron ore and bituminous coal) due to diplomatic friction between China and Australia. This has caused a lot of damage to the people who contracted for the sale and the construction companies that are trying to sell it. Therefore, it is necessary to consider the economic feasibility of this reinforced concrete.

Geothermal power produces electricity as an energy source for the earth's internal heat. The temperature in the ground, close to the earth's surface, is kept at around 10~20℃. With these characteristics, it is possible to build a heating and cooling system using a heat pump. The heat exchange with the ground is carried out through a heat exchanger, in which the refrigerant acts as a medium for heat transfer [1]. Generally, the heat exchanger is completed by drilling a hole of 100 meters, inserting a U-shaped tube, and filling the space between the tube and the hole with grouting material [2].

As a result, there have been prior studies on geothermal energy technology. To reduce the cost of rebar materials and use geothermal energy, pipe rebar can be used as a geothermal energy equipment material [3].

According to the U.S. Environmental Protection Agency (EPA), the geothermal source heat pump system is the most energy-efficient, environmentally friendly and cost-effective heating and cooling technology available. Energy savings of up to 72% [4]. However, research on the corrosion properties of pipe rebar and the corrosiveness of refrigerant in pipe of geothermal power structure has not yet been conducted. As a construction material used in land buildings, offshore buildings, etc., pipe rebar can be used as a substitute for existing rebar.

Therefore, there is a need to consider corrosion of pipe rebar, which is a replacement for the previously used rebar.

II. Experimental Procedure

A. Specimens

Rebar is made by making protrusions on the surface of small-diameter thick steel pipe.

More than doubled yield strength to maintain the strength of existing rebar (Class 400MPa → Class 800MPa).

The diameter of the rebar was 25 mm (D25). In the case of pipe rebar, the interior is hollow and the thickness of the pipe is 3mm as shown in the Figure 1.

The protrusion-shaped surface secures adhesion performance with concrete [5]. Reinforcement steel is used to ensure a level of strength equal to that of conventional rebar but weight is reduced by half for improved stability, economy and eco-friendliness.

Figure 1. Preparing pipe rebar and used rebar for experiments

B. Experimental Procedure

In order to perform an experiment to evaluate the corrosion characteristics of rebar, the rebar test specimen was exposed to various experimental aqueous solution environmental conditions such as deaerated water, deionized water, antifreeze water, antirust water, tap water, natural seawater, 5% salt water [6].

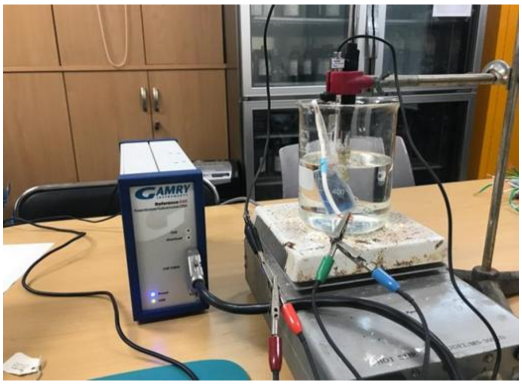
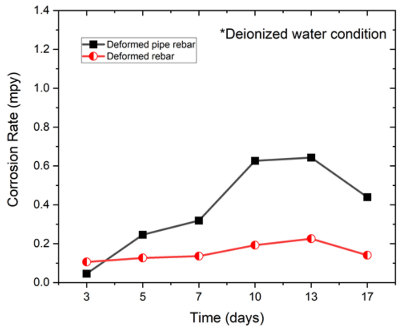
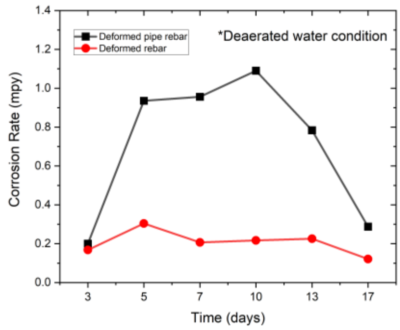


Figure 2. Experimental apparatus (Gamry reference 600)

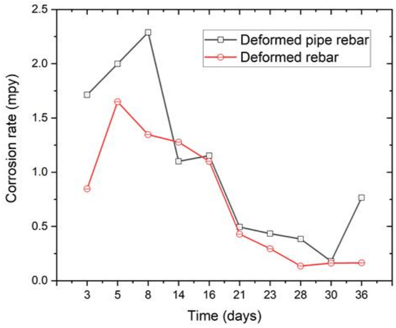
After the specimen was immersed in various corrosion aqueous solutions, the corrosion potential and corrosion rate were measured once a day for the initial month and once a week thereafter. The corrosion rate was performed in accordance with ASTM Practice G61 and a potentiodynamic polarization test. The corrosion rate was calculated by the method of linear polarization resistance method. Silver/Silver chloride reference electrode (SSCE), and platinum counter electrode were used for potential measurement and polarization. Linear polarization resistance test was measured at range from -20mV to +20mV vs. Eocp(open circuit potential) with scan rate of 0.5mV/s, and potentiodynamic polarization test was carried out at range from -500mV to +1,500mV vs. Eocp(open circuit potential) with scan rate of 1.0mV/s for confirming the corrosion trend and passivity characteristics [7-10]. Measuring data were automatically stored in Gamry Reference 600 Potentiostat units with a computer in Figure 2.



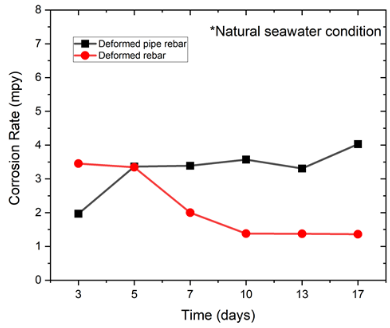
(a) CR in deionized water



(b) CR in deaerated water



(c) CR in tap water



(d) CR in natural seawater

Figure 3. Corrosion rate (CR) results in various corrosive solution environment

III. Experimental results

Figure 3 present the corrosion rate results to compare between pipe rebar and normal rebar at different corrosive conditions.

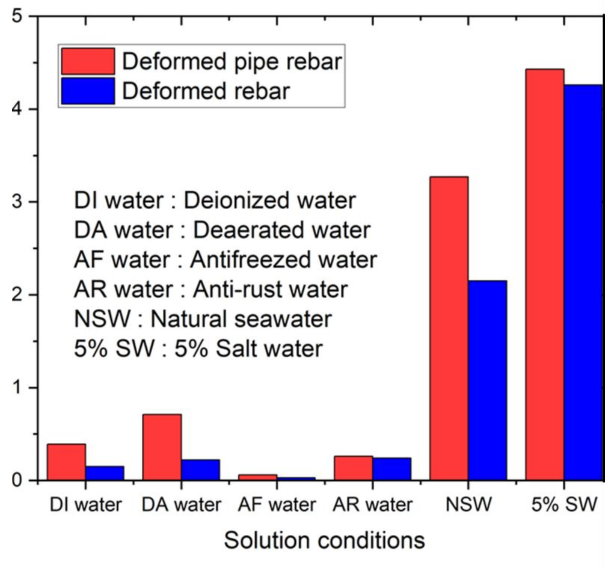


Figure 4. Calculated mean corrosion rate (mpy) in various corrosive conditions

After the rebar was immersed in 4 kinds of corrosive environment aqueous solution, the corrosion rate was measured at regular intervals, and the corrosion rate was measured high in the seawater environment, and the corrosion rate was relatively low in the environment of deionized water, deaerated deionized water, and tap water.

In most corrosive conditions, corrosion rate of pipe rebar much higher than that of normal rebar. Because hollow pipe rebar is made twice as high in strength to ensure same strength.

Table 1. Calculated mean corrosion rate (mpy, mm/year) and service life (year)

Conditions	Corrosion rate (mpy)	Corrosion rate (mm/yr)	Service life (year)
Deionized water	0.39	0.009906	303
Deaerated water	0.71	0.018034	166
Antirust water	0.26	0.006604	454
Antifreeze water	0.06	0.001524	1969
Natural seawater	3.27	0.083058	36
5% salt water	4.43	0.112522	27

As a result of calculating the average corrosion rate, the corrosion rate was measured as the lowest in an aqueous antifreeze solution environment in Figure 4. The corrosion rate was relatively low in the environment of deionized water, deaerated deionized water, antifreeze, and aqueous anti-rust agent. In most corrosive conditions, corrosion rate of pipe rebar much higher than that of normal rebar.

Because thickness of pipe rebar was 3mm. We can calculated the service lifetime from the measuring corrosion rate results in Table 1. Assuming that uniform corrosion occurs inside a 3mm thick pipe rebar, the service lifetime of pipe rebar is calculated to be about 1969 years in antifreeze water condition. Since the corrosion rate is 0.06mpy of antifreeze water, the corresponding lifetime is about 1969 years [11].

In most corrosive conditions, corrosion rate of pipe rebar much higher than that of normal rebar.

In figure 5 indicating the anodic polarization curves from potentiodynamic polarization measurement in deionized water, natural seawater, and antifreeze water for confirming the corrosion trend and passivity characteristics [12]. Both deionized water, and natural seawater condition are indicated similar behavior but the curve of red line measured in natural seawater lied more right side and lower positon. That means corrosion rate in seawater condition faster than in deionized water condition. In case of antifreeze condition, corrosion rate almost same with corrosion rate in deionized water, but passivity potential range from -200mV to +600mV vs. SSCE is clearly visible unlike other two conditions. Especially, passivity behavior which current density is maintained by increasing potential also appeared from green lines in antifreeze water condition which means that passive film formed on the surface of the rebar is not burst and is well maintained. Under the antifreeze water condition, not only the corrosion rate is low, but also the passivation characteristics are analyzed as good [13].

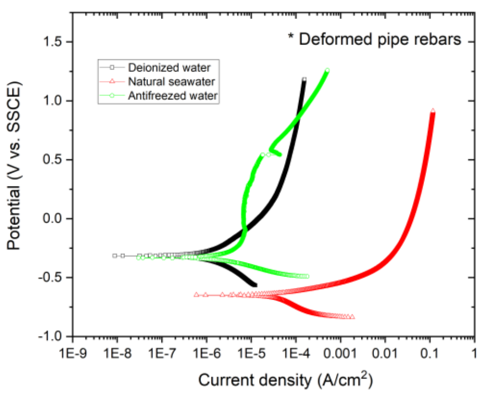


Figure 5. Potentiodynamic polarization measurement results in various corrosive conditions

IV. CONCLUSIONS

After the rebar was immersed in 6 kinds of corrosive environment aqueous solution, the corrosion rate was measured at regular intervals, and the corrosion rate was measured high in the seawater environment, and the corrosion rate was relatively low in the environment of deionized water, deaerated deionized water, antifreeze, and aqueous anti-rust agent.

The measurement of the corrosion rate behavior of pipe rebar test specimens and general rebar test specimens showed that the corrosion rate of pipe rebar test specimens was fast under almost all corrosion aqueous solution environmental conditions.

Compared with general rebar, the corrosion potential, corrosion current density and passivation characteristics of pipe rebar were measured to be inferior.

As a result of calculating the average corrosion rate, the corrosion rate was measured as the lowest in an aqueous antifreeze solution environment. Assuming that uniform corrosion occurs inside a 3mm thick hollow rebar, the life of hollow rebar is calculated to be about 1969 years.

Through corrosion experiments, it was confirmed that when antifreeze is used as a circulating refrigerant inside pipe rebar, geothermal energy can be utilized without corrosion problems of pipe rebar during the life of the structure.

As a result of the experiment, it was judged that pipe rebar can be used as an alternative to the general rebar used in existing buildings. In addition, it was found that pipe rebar can be used as a geothermal heat exchanger piping.

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