Grounding Characteristic Analysis of Plate Electrodes

Sung-Sam Kim* · Ju-Chan Kim · Hee-Seog Koh

Abstract

In this study, an experiment on the efficient construction method of plate electrodes, the influence of electric potential interference in plate electrodes, and building foundations were explored. The experimental result of the electric potential measurement was taken on the basis of the direction of movement and the condition in which the plate electrodes are laid underground in building foundations. It shows that the construction method of laying the plate electrodes vertically exhibits a more efficient reduction of electric potential in a diagonal direction and on an X axis than laying plates horizontally. For plate electrode construction in an area that has uniform conditions, the parallel joint construction method is more effective than a single construction to reduce earth electrical potential and ground resistance. In addition, a straight arrangement performs well in ground efficiency, compared to the parallel arrangement.

Key Words : Building foundation, Plate electrode, Potential interference, Potential rise

1. Introduction

Reduced conducting wire must be constructed with a double voltage path and a minimum LPS length which is necessary to prevent damage during lightning strikes.

Along with this, horizontal conductors, which connect every reduced conducting wire from the ground of the building at an interval of 10~20[m], should be constructed to evenly carry lightning current as a conductor cable.

International Standards and KS concerning lightning strike equipment regulate the down conduction wire. This wire needs not only a horizontal conductor, but also the security of an inner space between the main electronic equipment of the building. In reality, however, the construction of a horizontal conductor and an inner buffer space has a high construction expense and impede the construction process.

If, however, a steel structural form is used instead of a reduced conductor, the steel structure will function as a conductor which carries lightning current with a shield effectiveness. Therefore, related regulations permit the use of a steel structural form which is used as a substitute for reduced conducting wire.

Since a steel structural form is used instead of a reduced conducting wire, it does not require the construction of a horizontal conductor and inner space thanks to its electrical conduction properties.

* Main author : Kyungnam University. Electrical Engineering
Tel : +82-55-249-2628, Fax : +82-55-249-2839
E-mail : dandissam@naver.com
Date of submit : 2007. 1. 16
First assessment : 2007. 1. 19
Completion of assessment : 2007. 2. 9

This can reduce construction expenses and improve construction processes. Still, the steel structural form needs electrical continuance to act as a proper substitute. Newly-enacted International standards say this about the evaluation standard,: If the electric resistance is below 0.2[Ω] between the upper and the lower areas of the steel structure, it ensures an electrical continuance.

This research analyzes the efficient construction method of plate electrodes and the influence of electric potential interference in plate electrodes when a steel-frame foundation is used as a reduced conducting wire or grounding structure through the use of an electrode pole and simulation water tank[2]. The arrangement of the plate electrode, the effectiveness of the reduction of electric potential in terms of forms, and aspects of variation were all observed. The ground resistance result of a single electrode was compared to a parallel electrode based on the same plate area. The minimum inner was further inspected by a single electrode to understand the parallel effectiveness of plate electrodes using the simulation water tank equipment[3-5]. Finally, the ground resistance was measured according to the distant variant between a vertical parallel and a straight arrangement.

2. Intervention of electric potential within the foundation of a building

2.1 Experimental equipment and methods

Fig. 1 shows a building foundation model for the experiment of the influence of electric potential interference in plate electrodes and building foundations. The assumed building founding electrode A and plate electrode B were manufactured as in the model. The numerical value of the model is as follows.

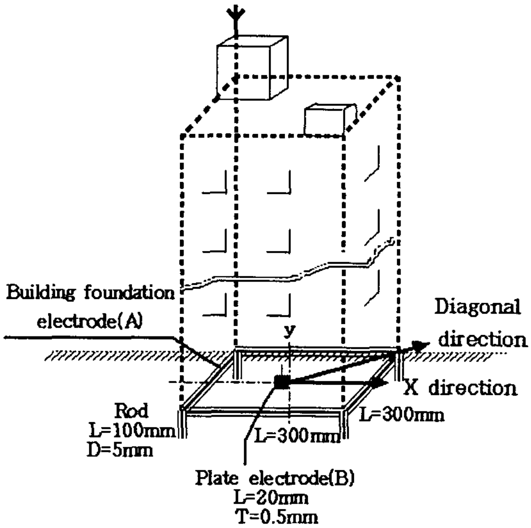
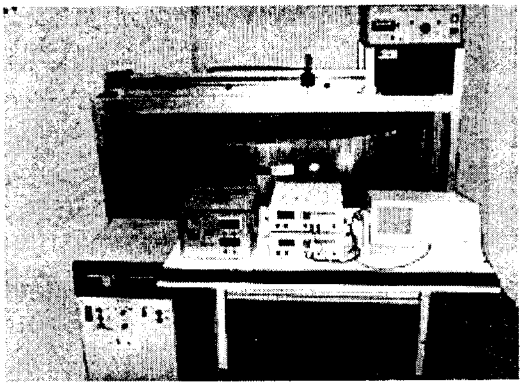


Fig. 1. Building foundation model

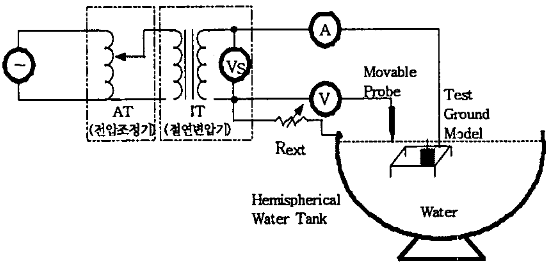
Table 1. Specification of model electrode

Electrode	Building foundation electrode	Plate electrode
standard	Foundation electrode L=300[mm] basic Pile(Rod) L=100[mm], D=5[mm]	Plate electrode L=20[mm], T=0.5[mm]

The coefficient of the electric potential interference was calculated by following the order after the electric potential was measured. First electrode A was arranged on the surface of the water at a mid water tank position. Then, electrode B was moved into the X axis and the diagonal direction of electrode A, while changing the depth of electrode B from the water surface to 150[mm] based on the vertical and horizontal arrangement. Fig. 2 shows the outer form and the equipment involved.



(a) Outer form(shape)



(b) Calculated circuit

Fig. 2. Experiment Equipment

The method of the model experiment of the ground was to arrange a scale model of the ground electrode in the water tank(Fig. 2). The device consists of a single phase 220[V], 60[Hz] power supply of alternating current, a movable electric potential device for measuring the point of measurement and the rising of electric potential of the water surface, a plate and the building foundation electrode, and a hemispherical water tank.

Electrode A, which was reduced by an arbitrary reduction scale, was installed under and at the middle of the water surface and a current was generated between electrode A and the exterior of the water tank. Then, the rising of the electric potential of the water surface was measured using the probe. The probe, which measures the rising of the electric potential, was installed on a movable device for measuring electric potential. This device gauges the electric potential on the surface or in the water, and was transferred by a conveyer through the diameter of water tank. Also, the position of the probe was marked in the device for measuring electric potential. The variable resistance in Fig. 2 means the resistance of the hemispherical to an infinite point. The reliance value was designated as 6[Ω] for the volume of the hemispherical and the ground moment of resistance. Tap water with a 27.9[Ω · m] moment of resistance was used to simulate the characteristic of soil.

A voltmeter(Vs), which indicates the applied voltage, simulated the voltage between electrode A and the infinite point; the voltmeter(V) showed the earth electric potential between the probe and the infinite point. In addition, the amperemeter(A) measured the current flow in the water tank and calculated the ground resistance as a ratio of the indicating value of the voltmeter and amperemeter. The applied voltage and rising of the electric potential of the water surface were detected by an oscilloscope [3-4].

2.2 Results of measurement and consideration

The electric potential interference means that electrode B was interfered with by the rising of the electric potential of electrode A. The coefficient of the electric potential interference, K, was defined by the following formula (1) as a standard with which to measure the degree of the electric potential interference on the electrode B.

$$K = \frac{\text{Electric potential of ground electrode B}}{\text{Electric potential of ground electrode A}} \quad (1)$$

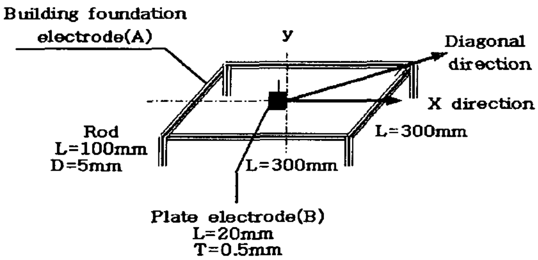


Fig. 3. Experiment model

Fig. 4 shows the results of moving electrode B toward the X direction of electrode A as in Fig. 3. This was based on the condition that electrode A was generated by a 50[mA] ground current. Fig. 5 shows the results of the diagonal direction, as well.

These results show that the vertical laying construction method exhibits a more efficient reduction of the electric potential in a diagonal direction and on the X axis than the horizontal laying construction method.

This reveals that the electric potential of the center or edge of a building is more even than the electric potential of the edge. It was found that the rising and interference of the electric potential decreased the farther it was from the plot. In particular, it can be seen that the electric potential is increased rapidly by the electric potential's interference on a basic pile when the plate electrode moves in a diagonal direction. Therefore, it was determined that the center of a building is more efficient than the edge regarding ground resistance and the reduction of the electric potential for the construction of a ground electrode within the plot of a building foundation. For this reason, in the case of industrial settings and

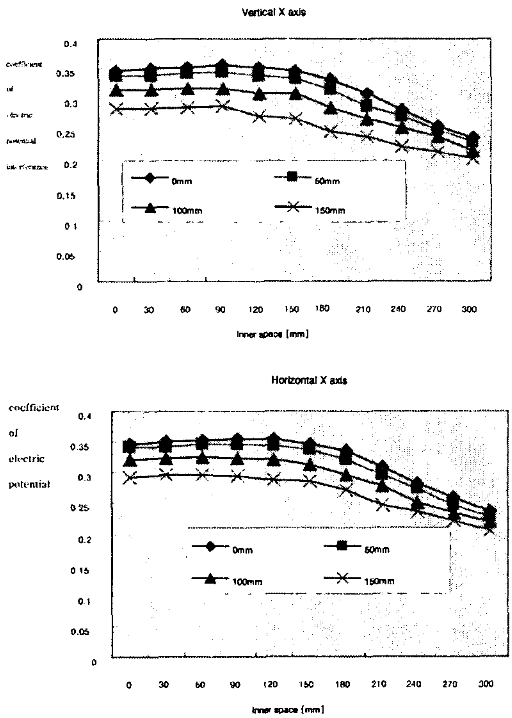


Fig. 4. X axis result graph

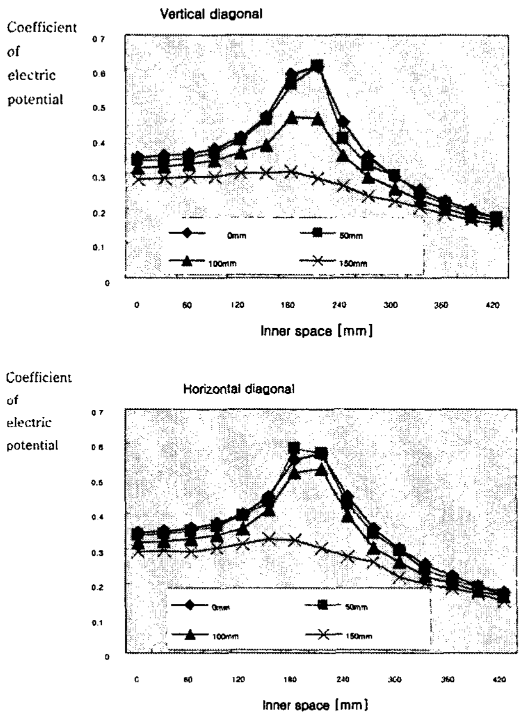


Fig. 5. diagonal result graph

manufacturing plants, the ground electrode should be constructed a long distance from the plot of the building construction, if possible.

This can prevent electrical accidents from the displacement of dangerous voltage such as touch and step voltages. Moreover, it is effective for ensuring safe operations.

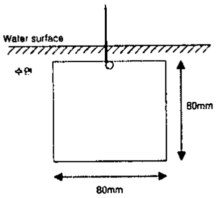
From the result graph of the laying depth of electrode B 150[mm], it was determine that the laying electrode should be deeper than the minimum basic Pile when it is constructed to reduce the electric potential interference in terms of laying direction and vertical and horizontal conditions of electrode B.

3. Characteristics of the ground resistance of plate electrodes

3.1 Experimental equipment and methods

Through this experiment, it was found that the vertical laying construction method exhibits more efficiency in reducing ground resistance and electric potential interference than the horizontal laying construction method.

The ground resistance characteristics of the parallel electrode and the single electrode were compared under the same area conditions with the water tank equipment.



(a) Single electrode (b) Parallel electrode

Fig. 6. Plate Electrode model

The scale of the palate electrode is 80×80[mm] for the single electrode and 57×57[mm] for the parallel electrode(Fig. 6). The ground resistance and electric potential within a scale of 20~300[mm] were calculated to observe the minimum inner space of the parallel joint.

The ground resistance was also measured to check the characteristics of the ground resistance of parallel plate electrodes when the electrode model differs in range between each electrode in both a vertical parallel arrangement and a straight arrangement(Fig. 7). The size of the plate of the electrode was 50[mm] each for length and width. The laying depth was 50[mm] and the inner space between each electrode was 10~100[mm].

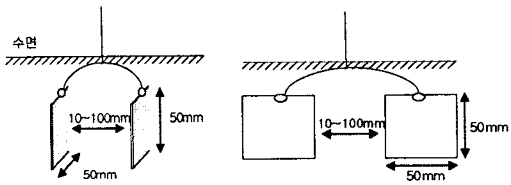


Fig. 7. Parallel and straight arrangement of vertical parallels

3.2 Results of measurement and considerations

3.2.1 Singleness and parallel resistance of plate electrodes

A parallel joint refers to two electrodes of the same shape and size connected by the parallel method. The characteristic of a parallel ground is that its combined resistance can be changed according to the distance between electrodes.

In other words, if the interval is narrow between electrodes, the pathway of outward flowing ground current is limited and the current cable becomes dense because of mutual intervention[6-7].

For the plate electrode construction under the same area conditions, the parallel joint construction method is more effective than singleness to reduce the earth electric potential and ground resistance. If the calculation value of the 80×80[mm] single electrode of ground resistance is 34.42[Ω], the resulting values of the parallel joint in terms of the inner space variation can be seen in Table 2. There is a 31.27[Ω] parallel effect in the inner space 60[mm] within a parallel joint of a 57×57[mm] electrode. The ratio of the single resistance is calculated as 19[%] at 120[mm], which is double the size of the parallel plate electrode, and as 23[%] at 180[mm], which is three times that of the parallel plate electrode.

Table 2. Results of parallel resistance

Inner space [mm]	Resistance[Ω]	Ratio of reduction[%]	Size of plate compared with parallel electrode
20	39.98		
40	34.82		
60	31.27	9.14	
80	29.21	15.12	
100	28.47	17.28	
120	27.87	19.03	Double
140	27.48	20.16	
160	27.01	21.52	
180	26.60	22.70	Triple
200	26.29	23.62	
220	26.09	24.20	
240	26.07	24.25	Quadruple
260	25.83	24.94	
280	25.58	25.67	
300	25.55	25.76	Quintuple

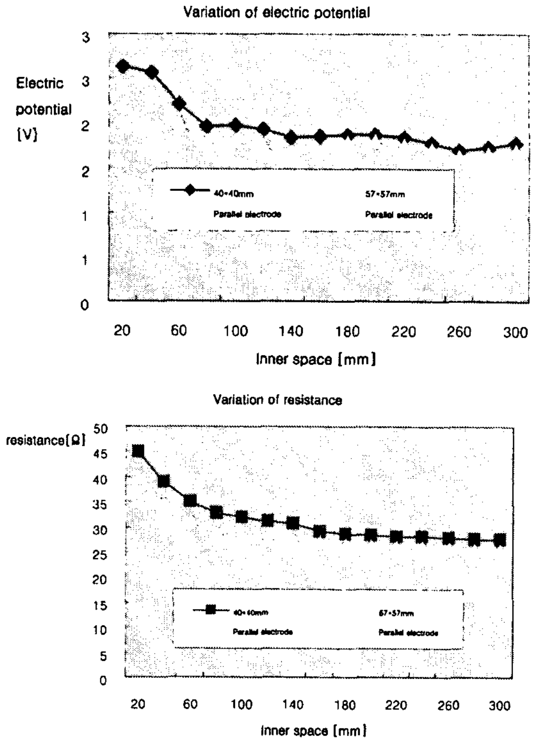


Fig. 8. Variations of parallel connections

As can be seen in the chart, the ratio of reduction tends to be higher as the inner space is larger; however, it is more efficient to construct twice or three times the amount of inner space of the plate size, in that it is more effective in terms of hours of installation, economical efficiency and a reduction of electric potential.

The same result effect was revealed and showed reliability and reproducibility in parallel electrodes with a scale of 40×40[mm]; it's the variation graph is described in Fig. 8.

3.2.2 Vertical parallel and straight arrangement

From the results of the vertical parallel and straight arrangement of the plate electrode, it was found that the singleness joint is more effective than the parallel regarding ground capability in an area with uniform conditions.

As can be seen from Fig. 3, ground resistance is lowered as the interval becomes larger.

Table 3. Results of vertical parallel and straight arrangement of plate electrodes

Inner space [mm]	Parallel arrangement[Ω]	Straight arrangement[Ω]	note[%]
10	64.54	50.5	27.8
20	58.8	49.33	19.2
30	54.60	48.53	12.5
40	51.33	47.1	9
50	50.44	46.62	8.2
60	49.36	46.14	7
70	48.35	45.66	5.9
80	46.5	45.5	2.2
90	46.28	45.02	2.8
100	45.99	44.7	2.9

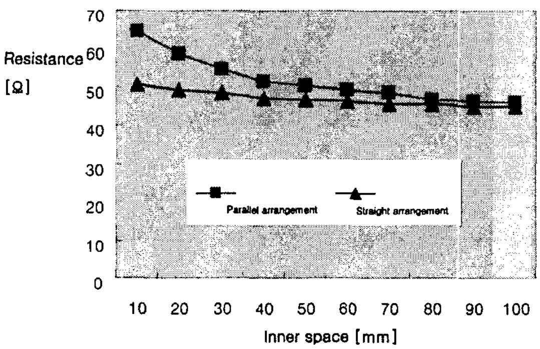


Fig. 9. Resistance variation of vertical parallel and straight arrangement

This result explains that the rising of the electric potential by the applied voltage has a greater impact in a parallel arrangement than the straight arrangement when close to the ground electrode. Further, as the laying depth is deeper, the ground resistance is lower due to the reduction of the rising electric potential. The ground is comparable to the experiment with the water tank.

4. Conclusion

This study experimented on the influence of electric potential interference in plate electrodes and building foundations as well as an effective construction method. The results are as follows.

1) The vertical laying construction method exhibits a more efficient reduction of electric potential in a diagonal direction and on the X axis than the horizontal laying construction method. The laying electrode should deeper than the minimum basic Pile when it is constructed to reduce electric potential interference in terms of laying direction and vertical and horizontal conditions of electrode B.
2) In uniform area condition, the parallel joint construction method is more effective than singleness to reduce earth electric potential and ground resistance. It is also more efficient to construct at twice or three times the inner space of the plate size, in that it is more effective for installation hours, economical efficiency and a reduction of electric potential.
3) It can be seen that the straight arrangement performs well in terms of ground efficiency, compared to the parallel arrangement.

This paper was completed using research expenses from the Kyungnam University Scientific dissertation publication in 2006.

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Biography

Sung-Sam Kim

1973. 5. 3. Graduated from Kyungnam University in 2001 with a Bachelors degree in electrical engineering. Graduated from Kyungnam University in 2003. (Master's degree). Is currently a Ph.D. student at Kyungnam University.

Ju-Chan Kim

1973. 9. 14. Graduated from Kyungnam University in 2000 with a Bachelors degree in electrical engineering. Graduated from Kyungnam University in 2002. (Master's degree). Is currently a Ph.D. student at Kyungnam University.

Hee-Seog Koh

1942. 8. 21. Graduated from Pusan University with a Bachelors degree in electrical engineering in 1966. Graduated from Chung-Ang University in 1985. (Ph.D). Vice-president of the Korean Institute of Electrical Engineers in 1999. Vice-president of The Korean Institute of Illuminating and Electrical Installation in 2005. Is currently a professor in the Department of Electrical Engineering at Kyungnam University.