

104. Rust Preventing Effect of an Inorganic Corrosion Inhibitor for Concrete by Brush Application

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1. PURPOSE

When corrosion of reinforcing steel is in progress due to salt contained in concrete, something has to be done to reinforced concrete structures to control corrosion of reinforcing steel and to prevent further loss in durability.

In the case of reinforced concrete, as a method to control the corrosion of reinforcing steel caused by salt content, there is a method to apply a corrosion inhibitor on concrete surface to permeate into the inside. To control the corrosion of reinforcing steel, it is necessary that the corrosion inhibitor permeated into the place where reinforcing steel exists and should maintain a concentration sufficient to control corrosion progress of the reinforcing steel. Here we tested and studied the necessary concentration of corrosion inhibitor which was permeated into the concrete.

2. TEST METHOD

2.1 MATERIALS

Materials used in the test are shown in Fig.1. The corrosion inhibitor used is available on the market and has a good permeability into concrete. It is made by 'O' company and has calcium nitrite as its main ingredient.

2.2 TEST

Six types of solution containing a certain percentage of ingredients as shown in Table 2 were prepared and each has concentration of 3.3%, 1.65%, 0.83%, 0.61%, 0.41% and 0.31% in NaCl at the time its chloride ion becomes equal. Here we call these solutions as corrosive solutions.

In accordance with the method of salt water immersion test for reinforcing steel in JIS A 6205, Corrosion Inhibitor for Reinforcing Steel in Concrete test apparatus as shown in Fig.1 was used. Reinforcing steels; one end processed to hemispheric state, overall surface polished with abrasive paper and degreased with acetone was dipped into corrosive solutions having different concentration. These reinforcing steels were left in the solution for three days during which time, change in the spontaneous electrode potential was measured and the condition in which corrosion of reinforcing steels progressing was prepared. The spontaneous electrode potential was measured. A while adding a very small quantity of corrosion inhibitor to this corrosive solution. And after the spontaneous electrode potential changed direction from base to noble and when the spontaneous

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electrode potential changed no more, the dripping was stopped. Measuring of spontaneous electrode potential was continued and its direction did not change again from noble to base in two or three days, the added amount of corrosion inhibitor was regarded as the amount required to control the corrosion of reinforcing steel. Then, to confirm that the corrosion of steel can be controlled, corrosion inhibitor of the same quantity and a half were added at once to the corrosive solution containing the reinforcing steel after three days spontaneous electrode potential was measured during the following seven days while corrosion was in progress.

3. RESULT AND OBSERVATION

Fig.2 shows the measurement of spontaneous electrode potential when corrosion inhibitor of the quantity required to control corrosion of reinforcing steel was added all at once. In all corrosive solution of different concentration before adding corrosion inhibitor, corrosion spreads at the spontaneous electrode potential of a little less than -1000mV , and the part of reinforcing steel rusts all over immersed in the corrosive solution. With the addition of corrosion inhibitor the spontaneous electrode potential changes quickly from base to noble and with further lapse of time the spontaneous electrode potential stabilizes at a value near zero. By adding the required amount of corrosion inhibitor in this way the corrosion of reinforcing steel in the corrosive solution stopped spreading.

Table 3 shows the quantity of corrosion inhibitor required to control the spread of corrosion of reinforcing steel in conversion of NO_2 ion for six types of corrosive solutions. As the salt concentration becomes higher, the quantity of NO_2 ion required for corrosion control tends to increase, however when the salt content becomes higher, rate of increase of required NO_2 ion decreases.

Table 4, on the basis of the test result in Table 3, shows the required quantity of NO_2 ion corresponding to the salt concentration contained in the concrete. The required NO_2 ion is based on the assumption that corrosion of carbonated reinforcing steel can be controlled with the quantity of NO_2 ion required to control the spread of corrosion of reinforcing steel tested in the corrosive solution. Assuming a concrete made with mixing water containing six types of salt content as used in the test, we determined the quantity of chloride ion contained in the concrete of 1m^3 , and salt content in fine aggregates when the same quantity of salt is contained in the fine aggregates, and the concentration of NO_2 ion to be contained in the concrete required to control the corrosion of reinforcing steel inside the concrete.

Fig.3 shows the relations between the quantity of chloride ion contained in a concrete of 1m^3 and the concentration of NO_2 ion to be contained in concrete to control the spread of corrosion of reinforcing steel. In concrete containing $600\text{gr}/\text{m}^3$ of chloride ion, or the maximum permissible quantity of chloride ion specified in revised JASS, the quantity of corrosion inhibitor required to control corrosion of reinforcing steel is around 0.017% in conversion of NO_2 ion concentration.

In reinforced concrete structures where corrosion of reinforcing steel by salt content come into question, many cases are found where salt content in concrete is considerably high, and therefore, it is necessary to study a method to control the spread of corrosion of reinforcing steel assuming a several times more salt content than the chloride ion specified in the

aforementioned revised JASS. In this case the quantity of corrosion inhibitor required to control the corrosion of reinforcing steel is around 0.02 to 0.04% in conversion of NO_2 ion.

According to the test to apply this corrosion inhibitor onto the concrete surface and permeate it into the inside, it is observed that corrosion inhibitor applied by a proper method can permeate into the inside of concrete within a short period of time after application and that the concentration of NO_2 ion is permeated to a considerable depth. Therefore, by applying a corrosion inhibitor onto the concrete surface to permeate inside, it is expected that spread of corrosion of reinforcing steel can be controlled. Fig.4 shows a case study of an exterior sidewall of reinforced concrete with 13 years after placing.

Fig.4 shows the concentration of corrosion inhibitor permeated into the inside of concrete after brush applying the corrosion inhibitor to the exterior wall of the subject of the case study. Depths from the concrete surface are shown on the horizontal axis, and they are shown for the age of one month, three months, six months and one year. In Fig.4 the concentration of NO_2 ion required to control corrosion of reinforcing steel is shown in black dots. It means that when the concentration of corrosion inhibitor permeates into inside of the concrete by brush application is higher than this black dot, the corrosion of reinforcing steel can be controlled. From Fig.4 it can be seen that the concentration of corrosion inhibitor permeated by brush application is considerably higher until around 3cm from the concrete surface than that required to control the corrosion of reinforcing steel, and therefore, the effect to control the corrosion of reinforcing steel can be well expected. At the depth of 5-6cm from the concrete surface, as times goes on after the application of corrosion inhibitor onto the concrete surface, the concentration of corrosion inhibitor increases gradually, and it nears the quantity required to control corrosion of reinforcing steel in half to one year after the application of the corrosion inhibitor.

4. CONCLUSION

The quantity of corrosion inhibitor required to control the spread of corrosion of reinforcing steel is 0.017% in conversion of NO_2 ion concentration when the quantity of chloride ion in concrete is $600\text{gr}/\text{m}^3$, and 0.02 to 0.025% when the quantity of chloride ion is in the range between $1000\text{gr}/\text{m}^3$ and $3000\text{gr}/\text{m}^3$.

According to the case study conducted with an existing reinforced concrete wall, the content of chloride ion in this concrete is around $1000\text{gr}/\text{m}^3$ and in this case the quantity of corrosion inhibitor required to control corrosion of reinforcing steel amounts to 0.02 to 0.025% in conversion of NO_2 ion concentration. An actual application of corrosion inhibitor onto a concrete surface by proper method proved that the quantity is sufficient to control corrosion of reinforcing steel.

Table 1 Test Materials

Corrosion Inhibitor	Goods on the market containing calcium nitrite as main ingredient
Sodium Chloride, Magnesium Chloride, Sodium Sulfate, Calcium Chloride, Potassium Chloride, Calcium Dioxide, Reinforcing Bar, Comparison Electrode, Water	As specified in appendix 1 of JIS A 6205 corrosion inhibitor for reinforcing steel in concrete

Table 2 Ingredients of corrosive solution

Ingredients	percentage
Sodium Chloride (NaCl)	100
Magnesium Chloride ($MgCl_2 \cdot 6H_2O$)	45
Sodium Sulfate (Na_2SO_4)	17
Calcium Chloride ($CaCl_2$)	5
Potassium Chloride (KCl)	3

Table 3

Concentration of corrosive solution in NaCl conversion (%)	Concentration of corrosion inhibitor converted to NO_2 ion (%)
3.30	0.39
1.65	0.33
0.83	0.27
0.61	0.23
0.41	0.07
0.31	0.03

Table 4 Per concrete of 1 m³ containing 180 kg of water and 800 kg of fine aggregates

Concentration of NaCl in mixing water (%) (A)	(A) converted to the quantity of chloride ion (g) (B)	(B) converted to the content rate of NaCl in fine aggregates (%)	Concentration (%) required for control of reinforcing steel corrosion
3.30	3605	0.74	0.031
1.65	1800	0.37	0.026
0.83	905	0.19	0.021
0.61	665	0.14	0.018
0.41	450	0.09	0.013
0.31	340	0.07	0.010

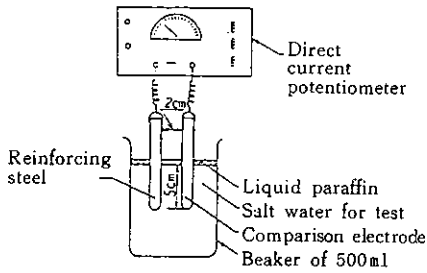


Fig. 1

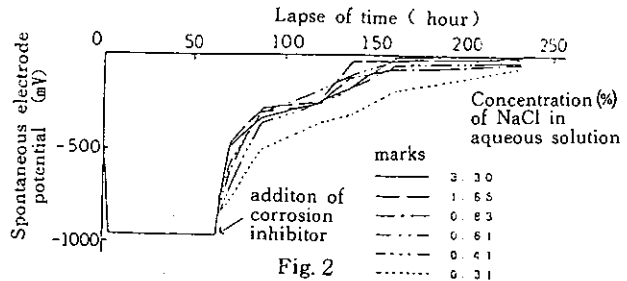


Fig. 2

Fig. 2 Case in which all the quantity required to control corrosion of reinforcing steel was added at once

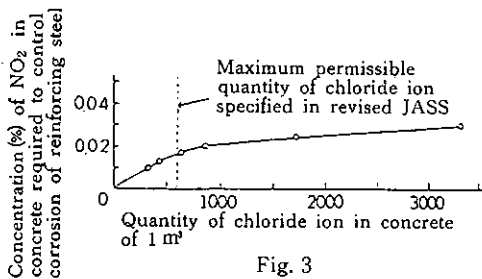


Fig. 3

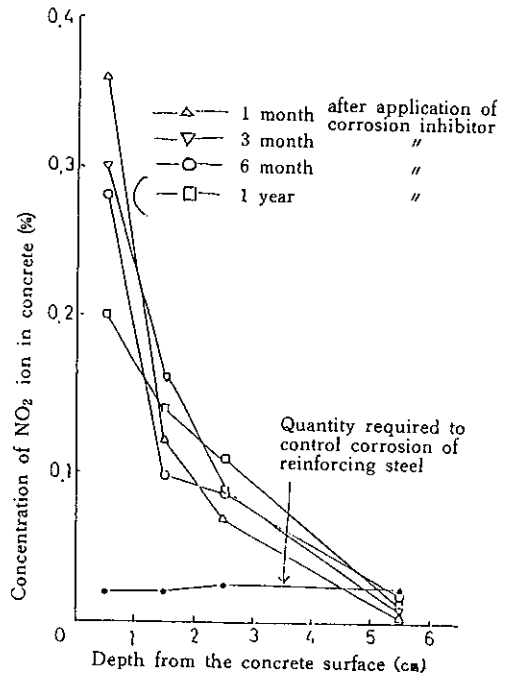


Fig. 4