

The Development of Slag Based Materials for the Reformation of Soft Ground

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For the development of reformation material of soft ground using the LD slag, the relation to the particle condition of LD slag and the pH behavior of slag dissolution water, extraction properties of slag, and origination of white water were investigated. When the LD slag is mixed with sea water, the pH of solution ranged between 9.47 and 10.0. On the other hand, when mixed with distilled water, the pH was about 10.4 to 12.1. For the as-received slag and the aged slag in sea water, a pH of 11.5 to 12.0 was observed when the particle size was less than 0.5mm. For the reoxidized slag in seawater, the pH of the solution was lower than 9.5 when the particle size was bigger than 0.075mm. For the aged slag and reoxidized slag, the pH of the solution remained constant when the addition ratio of sea water to the slag was higher than 500 times. The main elements dissolved from the slag were Ca and Mg ions. When the pH went over 9.0, the white water started to form, which was caused by the CaCO_3 and $\text{Mg}(\text{OH})_2$.

Keywords : LD slag, reformation material, soft ground, steel slag.

1. Introduction

During the last 10 years, the steel slags produced from iron making steel works have been widely applied in roadbed materials, civil engineering works, cement clinker materials, and soil conditioner.[1-2] Recently, the application studies in the marine environment for the mass utilization of steel slags are attempted .[3-5] Among the steel slags, especially LD slag is restricted in the application of aggregates for the public works owing to the volumetric expansion which is induced from free lime in slag. In this paper, the utilization plan of the LD slag as reformation materials of soft ground for the harbor construction works was investigated. This paper describes that the relation to the particle condition of LD slag and chemical properties such as pH and dissolution

ions of the slag dissolution water, and formation of the white water in the condition of contact with LD slag and sea water.

2. Experiment

The LD slag samples used in this experiment were 3 types, which are the as-received slag produced at steel making factory, the aged slag manufactured by steam aging, and the reoxidized slag manufactured by air blowing and cooling the molten slag. The LD slag having a particle size of 0.045 to 4.75mm as experimental samples, and distilled water and sea water as a solvent were used respectively. The examination of pH for the slag dissolution water was performed on the basis of Korean extraction procedure test. After weighing

accurately 10g of slag which has different particle size and putting into solvent of 25ml and stirring for a certain time, we measured the pH in the upper portion of the solution by pH meter. The observation of pH variation with the mixing ratio of the LD slag and sea water was performed under the condition of stirring and non-stirring. The extraction property of the LD slag was done on the basis of Korean extraction procedure test. After putting the LD slag of 50g having a particle size of 0.5 to 4.75mm into the solvent of 500ml and agitating in the agitation apparatus, we determined the variation of extraction ions as a function of elapsed time. The formation process of white water which is originated with the reaction of the dissolution water of the LD slag and sea water was observed. The crystalline phase of the white precipitate was analyzed.

3. Results and Discussion

Fig.1 shows the pH of the slag dissolution water extracted under the condition of contact with distilled water and sea water. It clearly shows that the pH value measured in the distilled water is higher than that of measured in the sea water. This result indicated that the $[OH^-]$ ion extracted from the LD slag in the case of the distilled water is directly connected to the increment of the pH. However, the $[OH^-]$ ion in the case of the sea water is not directly linked to the increment of the pH owing to the reaction between $[OH^-]$ ion and various ions, $[HCO_3^-]$ ion which are dissolved in the sea water, that is, the capacity of buffering of sea water. When the slag was stirred for 30 minutes in the sea water, the pH of the solution for the as-received slag was increased rapidly. However, the increment of the pH for the aged slag and reoxidized slag was not remarkable.

Fig.2 shows the variation of pH of the solution for the fine particle size less than 0.045mm. In the case of the fine particle size, the pH value of the solution in the sea water was low, but there was no significant difference in

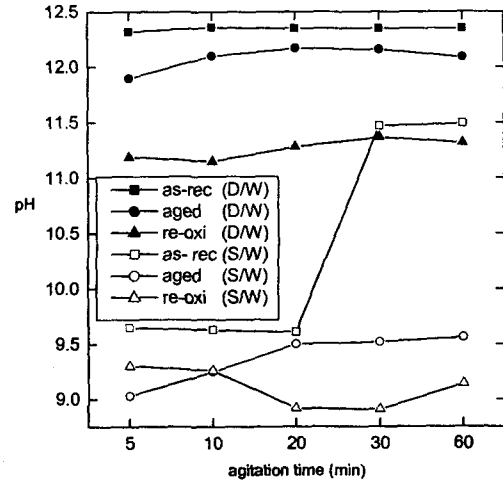


Fig.1 Change in pH of the slag dissolution water in the distilled water and sea water

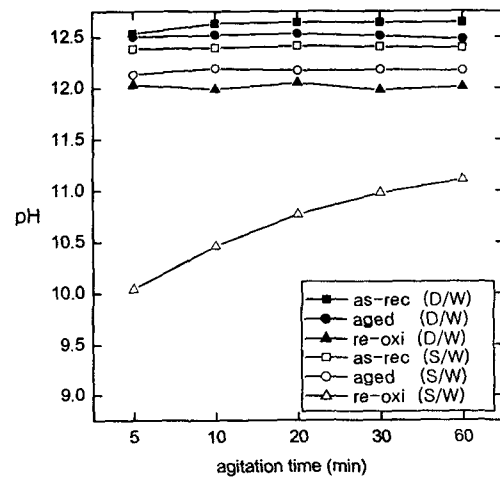


Fig.2 Variation in pH of the slag dissolution water for the fine particle size less than 0.045mm

the pH value between in the sea water and in the distilled water. The pH value of the solution for the reoxidized slag showed relatively low due to the stability in the solution.

Fig.3 shows how the pH is dependent on particle size. If a particle size of slag is bigger than 1mm in the sea water, there is a small change in the pH value for the as-received slag, aged slag and reoxidized slag. However, the pH value rapidly increase for the as-received slag and

aged slag if the particle size of slag is less than 0.5mm. In the case of the reoxidized slag having a particle size bigger than 0.075mm, the pH of the solution was not changed greatly. From this result, it is considered that the slag having a particle size bigger than 1mm is suitable for the reformation material of soft ground.

Fig.4 shows the variation of pH of the solution as a function of addition of sea water to the certain amount of slag. This experiment was performed in order to investigate of the influence on the pH of the sea water under the condition of contact with slag dissolution water and sea water.

For the aged and reoxidized slag, pH is independent of the amount of sea water when the ratio of sea water to the slag is over 500 times. Furthermore, in the case of the contact with actual sea water, the ratio of the sea water to the incoming slag dissolution water will be more than several thousands times as much. Therefore, it is considered that the pH of the slag dissolution water has no effect on the pH of the sea water. In the case of the non-stirring, as shown in Fig.5, when the addition ratio of the sea water to the slag was about 300 times, the variation of pH of the solution was not altered any more.

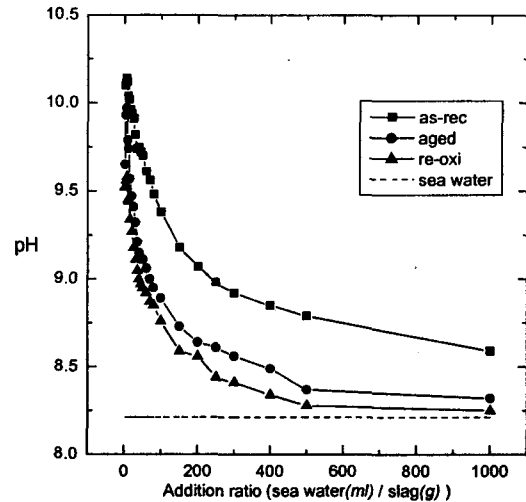


Fig.4 Variation in pH of the slag dissolution water as a function of addition of sea water to the slag (stirring)

Fig.6 shows the change in pH of the solution as a function of the increasing amount of slag in a fixed amount of sea water. When the reoxidized slag is used, it shows a relatively lower pH increase compared to the other two slags. The change in pH of the slag dissolution water with the progress of agitation time was listed in Table 1.

The pH of the slag dissolution water which was used distilled water as solvent showed higher value than

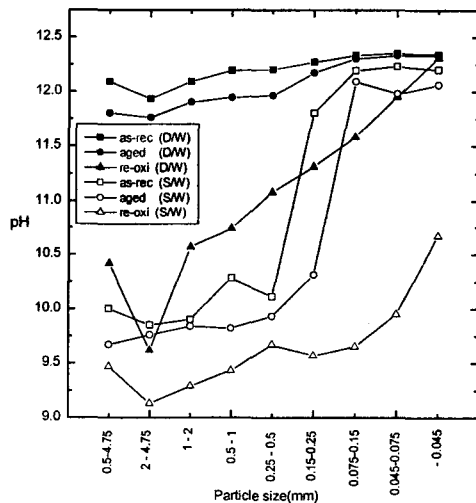


Fig.3 Variation in pH of the slag dissolution water with particle size

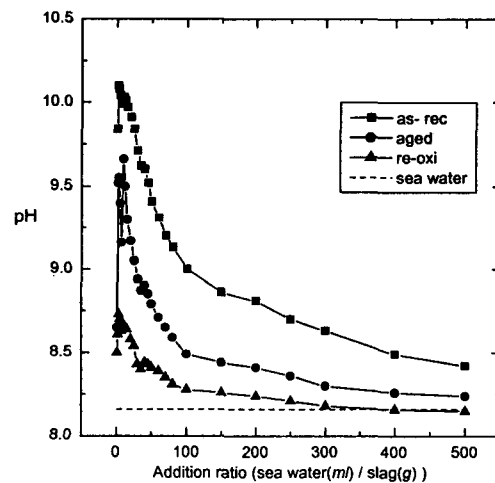


Fig.5 Variation in pH of the slag dissolution water as a function of addition of sea water to the slag (non-stirring)

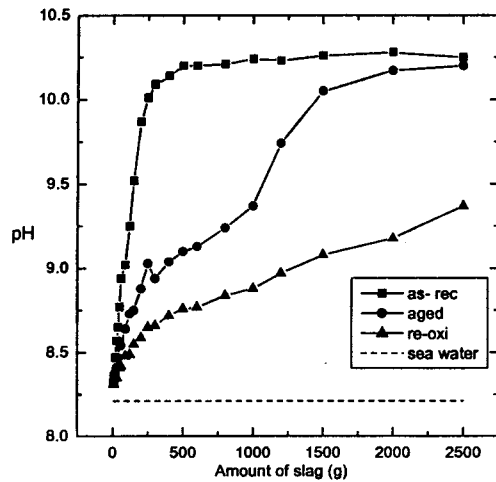


Fig.6 Change in pH of the slag dissolution water as a function of the increasing amount of slag in a fixed amount of sea water

Table 1 Change in pH of the slag dissolution water according to the agitation time (on the basis of Korean extraction procedure test)

slag & solvent		as received		aged		reoxidized	
		sea water	distilled water	sea water	distilled water	sea water	distilled water
starting pH		7.98	5.71	7.98	5.71	7.98	5.71
Extraction time (hr)	6	9.92	12.38	9.65	12.34	9.51	11.67
	24	10.92	12.5	9.55	12.31	9.5	11.65
	48	11.26	12.48	9.48	12.37	9.56	11.78
	72	11.38	12.48	9.7	12.38	9.54	11.81
	120	11.51	12.46	11.23	12.42	9.38	11.87

that of the in the sea water. For the as-received slag in seawater, the pH was between 10 to 11.5. Both the aged and reoxidized slags in sea water, however, had about pH 9, which is relatively low. The result of the chemical analysis for the extracted components with respect to agitation time was listed in Table 2. In the distilled water, the main element to dissolve was Ca ion. It is believed that no elements except for Ca ion are dissolved from the slag, however, some elements from the slag may be precipitated as hydroxides form considering the high pH value of the slag dissolution water. In the sea water, the main two elements to dissolve are the Ca and Mg ions. For the case of as-received slag, which has a higher pH, the concentration of Mg ion decreased to 27ppm after 1 day. After 2 days, we could not nearly detect the Mg ion in solution. This decrease can be explained by the precipitation of $Mg(OH)_2$ due to high pH value. Considering the concentration of Ca ion of 341 to 420 ppm in sea water, this data indicated that a large amount of Ca ion was extracted from the as-received slag and the aged slag, but comparatively low in the reoxidized slag. From this result, it was clearly confirmed that the amount of Ca ion extracted from the slag is closely related to the increment of pH.

Fig.7 shows the formation process of white precipitate

Table 2 Chemical compositions of the extracted components with respect to extraction time

	sea water extraction time (hr)	(unit:ppm)									distilled water extraction time (hr)	(unit:ppm)								
		Ca	Mg	Al	Fe	Si	Cl	Zn	Mn	Ca		Mg	Al	Fe	Si	Cl	Zn	Mn		
as-rec	6	1300.0	419.6	1.15	Tr	2.64	Tr	0.140	Tr	6	250.1	Tr	5.48	Tr	0.96	0.074	0.056	Tr		
	24	2039.0	27.0	1.76	Tr	6.40	Tr	0.250	Tr	24	252.0	Tr	7.88	Tr	1.52	Tr	Tr	Tr		
	48	2174.0	0.52	2.45	Tr	2.33	Tr	0.250	Tr	48	275.0	Tr	8.27	Tr	1.12	Tr	Tr	Tr		
	72	2017.0	0.42	1.76	Tr	3.20	Tr	0.240	Tr	72	276.5	Tr	9.97	0.067	0.93	0.059	Tr	Tr		
	120	1885.1	0.39	1.66	Tr	3.12	Tr	0.240	Tr	120	284.1	Tr	8.21	0.091	0.98	0.078	0.053	Tr		
aged	6	809.3	693.0	0.67	Tr	4.61	Tr	0.140	Tr	6	194.1	Tr	5.60	Tr	1.60	0.074	0.057	Tr		
	24	1223.0	440.5	1.15	Tr	0.96	Tr	0.110	Tr	24	185.8	Tr	12.13	Tr	2.10	0.025	Tr	Tr		
	48	1490.0	326.8	1.28	Tr	1.33	Tr	0.130	Tr	48	213.6	Tr	13.45	0.070	1.46	Tr	Tr	Tr		
	72	1823.0	128.8	1.66	Tr	1.38	Tr	0.130	Tr	72	227.2	Tr	12.75	0.087	1.09	0.070	0.066	Tr		
	120	2036.0	0.67	2.05	Tr	2.31	Tr	0.240	Tr	120	228.2	Tr	7.78	0.097	1.14	0.082	0.034	Tr		
re-oxi	6	477.0	936.0	0.36	Tr	6.53	0.014	0.097	Tr	6	63.0	0.22	0.73	Tr	14.77	0.030	Tr	Tr		
	24	559.0	885.0	0.42	Tr	5.03	0.053	0.073	Tr	24	63.4	0.16	0.73	Tr	18.24	0.064	Tr	Tr		
	48	599.0	886.0	0.45	Tr	1.05	0.071	0.089	Tr	48	81.2	0.12	0.70	Tr	12.91	0.068	Tr	Tr		
	72	666.0	806.0	0.63	Tr	1.28	0.120	0.100	Tr	72	80.9	0.12	0.70	Tr	9.20	0.074	Tr	Tr		
	120	806.0	702.0	0.77	Tr	0.28	0.140	0.100	Tr	120	90.6	0.08	0.85	Tr	7.11	0.088	0.030	Tr		

when the reacted with slag dissolution water and sea water. Initially, the pH of the solution rapidly increased. However, once it reached pH 10, it levels off and remains constant for a long time. The rapid initial increase in pH can be explained by the concentration of the $[\text{OH}^-]$ ions dissolved in the solution. However, the leveling off of pH at 10 is a result of the $[\text{OH}^-]$ ions starting to react with the other elements in the sea water. The white precipitate starts to form at pH 9.07 and the color of solution turns perfectly white when the pH is about 9.98. From the XRD pattern shown in Fig.8, the precipitates were analyzed as CaCO_3 and $\text{Mg}(\text{OH})_2$.

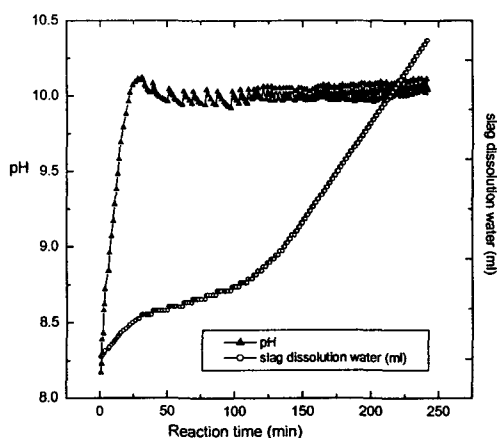


Fig.7 Formation process of white precipitate according to the reaction between slag dissolution water and sea water

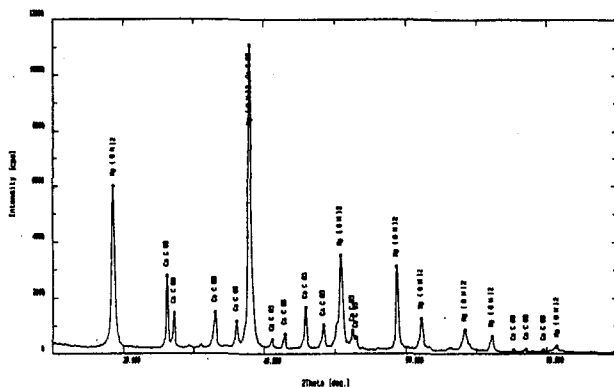


Fig. 8 XRD pattern of white precipitate

4. Conclusion

For the development of reformation material of soft ground using the LD slag, the relation to the particle condition of LD slag and the pH behavior of slag dissolution water, extraction property of slag, and origination of white water were investigated. The results obtained in the present study are summarized as follows: The pH of the solution made by the contact with sea water and LD slag ranged between 9.47 and 10.0. On the other hand, in the case of the distilled water, the pH was about 10.4 to 12.1.

For the as-received slag and the aged slag in sea water, a pH of 11.5 to 12.0 was observed when the particle size of the slag was less than 0.5mm.

For the reoxidized slag in sea water, the pH of the solution was lower than 9.5 when the particle size was bigger than 0.075mm.

For the aged slag and reoxidized slag, the pH of the solution remain constant when the ratio of sea water to the slag is higher than 500 times.

The main elements dissolved from the slag were Ca and Mg ions. When the pH went over 9.0, the white water started to form, which was caused by the CaCO_3 and $\text{Mg}(\text{OH})_2$.

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