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Development of Abandoned Mine backfill Material by Utilizing the Power Plant By-products

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Abstract.

The issue of mining cavern is an inevitable with mineral resource development, so a solution is necessary about mining cavern and land subsidence by not only abandoned mine but also operating property. Also, 65% of electric power production in Korea depends on the thermal power generation, and Korean government has a plan to increase 25 the thermal power generation by 6th power supply and demand policy due to recently nuclear accident in Japan. By increasing the thermal power generation, the substitute resource technology is necessary for mass amount ash of the thermal power generation; nine million ton of the thermal power generation ash occurred in 2012. For that reason, this study has done for utilization of mass amount ash from the thermal power generation as abandoned mine backfill material.

In this study, the strength and the expansion of CSA clinker with small amount of cement was increased about 30% compared with an existing OPC and the optimum mix was made to utilize mass amount of fly ash up to 90% in total mix. The optimum mix of fly ash and bottom ash together by CSA clinker cement can be solution of the thermal generation henceforth, then the mix of paste backfill method that is able to handle mass amount of ash was developed to the materials that can fill abandoned mine and underground cavern safely.

Keywords: Fly Ash, Bottom Ash, Backfill, Power Plant, By-products.

Acknowledgements
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Introduction

South Korea's future energy goals are outlined in biannual power development plans based on which generation companies apply for government approvals for power plant construction. The latest installment of the so-called "Basic Plan of Long-Term Electricity Supply and Demand (BPE)" is the 6th BPE, issued this year, which covers a planning period from 2013 to 2027[1]. Figure 1 shows the South Korea's future energy sources. Coal power has to date played a particularly marked role, its share in the country's electricity mix rising dramatically from 17% in 1990 to 40% in 2010. Gas-fired generation, too, soared during that period, from 9% to 19%. Though the country's "green growth" future strategy favours nuclear power most of all, coal will continue to play a major role, presumably to boost energy security. South Korea's energy consumption is still growing and Korea dependent on imports [2](Figure 2). Rising coal consumption in South Korea and a negligible production level have caused the country to rely heavily on imports over the past several years. South Korea held only 139 million short tons (MMst) of recoverable coal reserves in 2010, according to the World Energy Council estimates. The electric power sector accounts for 62% of the country's coal consumption, while the industrial sector accounts for most of the remaining amount, according to KEEI.

By products generation from coal power plants shows vigorous environmental impacts. Waste created by a typical coal plant includes more than 500,000 tons of ash (Table 1). Nationally, at least 42% of coal combustion by products is generated and it's run over to the waste ponds and landfills. In the United States alone about 130 million tons of coal combustion waste products are produced every year, which is about the same as all the residential solid waste generated in the US per year. Most coal power waste winds up in landfills, surface impoundments or in mines whereas smaller amounts are used for e.g. cement or concrete production. Rates of coal power waste recycling are high in some European countries, including the Netherlands, Denmark and Belgium, but worryingly low among the three largest consumers of coal, China, the US and India (33 percent, 38 percent and less than 5 percent respectively). Typically, solid waste is stored in landfills, while liquid waste is stored in impoundments. Ideally these disposal sites should be designed to prevent the toxic wastes from entering the environment. In Korea, based on the demand and policy, it has been plan to expansion new thermal power plants. In developed countries, ash recycling technologies are available to minimize the landfill problems.

Figure 3 shows the accidents associated with the limestone. The mine site conditions can affect the impact of dust generated during extraction, including rock properties, moisture, ambient air currents and prevailing winds, and the proximity to population centres. Fugitive dust can escape from trucks traveling on excavation haul roads and from blasting. This airborne dust can travel long distances from a mining site and affect urban and rural residential areas downwind. Some of the common methods of backfilling which are used according to economic factors and further goals such as development of mine or abandoning the mine are rock backfill, hydraulic backfill, cemented paste backfill, and silica alumina-based backfill methods (Figure.4).

2. Experimental Procedure

2.1.Flowability Test

Flowable backfill is a mixture of coarse aggregate, fine aggregate, water and air entraining agents, either cement or pozzolons or a combination of both, and may or may not include bottom ash, or other admixtures. There are three kinds of flowable backfill types and different types of materials to backfill i) cement ii) fly ash iii) ground granulated blast furnace slag iv)fine aggregate v) coarse aggregate vi) bottom ash vii) water viii) admixtures. Figure 5 shows the flowability test result. ACI 229 flow cone (976mm* 152 mm) measured the spread size of the mixed material in the third direction.

2.1 Compressive Strength Test and Length Changes Test

To understanding the compressive properties are of great interest. Higher water content resulted in higher compressive strength. Several researchers reported the compressive strength effect parameters and key factor controlling the compressive strength. (Figure.6) [3-6]. Under standard curing, measured by age shrink and expansion (Fig 7)

3.Results & Discussions

3.1 Fly ash and Bottom ash analysis result

The sample of YH_FA(PC boiler type) and YS_FA, DH_FA(CFBC boiler type) was subjected to partic le size, XRD analysis.(Table 2) XRD analysis results, YH_FA and DH_FA are a low CaO content, YS_FA is a CaO content of 16.3%. SEM analysis of the samples, All of the same was confirmed that t he shape of typical sphere Fly Ash.

The sample of YH_BA, TA_BA, SC_BA(PC boiler type)and YS_BA, DH_BA(CFBC boiler type) was sub jected to particle size, XRD analysis. .(Table 3)) XRD analysis results, YS_BA is a CaO content of 21. 6%. Sample-specific shapes are very different, and exhibited a very different particle size distribut ion. (Fig 9). Therefore, When the batch test of abandoned mine backfill material, very different shape and particle size distribution are expected and the shape large impact on the flowability, co mpressive strength.

3.2 Mine backfill Material batch test of Fly ash and Bottom ash

Abandoned mine backfill material batch test was conducted characteristics according to type dom estic Fly Ash(YH_FA, YS_FA, DH_FA) by OPC 5% blend and OPC 10% blend. Test item is flowability and 7day-28day compression strength. In OPC 5% blend batch test, YH_FA is the smaller proporti on of water was used, the compressive strength exhibited the following properties that the low ex pression. the other side, YS_FA is the more proportion of water was used, the compressive strengt h exhibited the following properties that the higher expression.(Table 4) In OPC 10% blend batch test, The experimental results showed that represents the trend is similar to OPC 5% blend batch test. But, Due to the high compressive strength of OPC content was found to be highly expressed t wice (Table 5).

Abandoned mine backfill material batch test was conducted characteristics according to type dom estic Bottom Ash(YH_BA, YS_BA, DH_BA) by OPC 5% blend and OPC 10% blend. Test items is flow ability and 7day-28day compression strength. In Experiment result, DH_BA mixed properties do n ot appear, remove the additional bottom ash particle size was used to draw conclusions that are a vailable throughout. YS_BA compressive strength of the preparation YH_BA showed the characteri stic to be expressed highly in OPC 5% blend batch test and OPC 5% blend batch test.

3.3 Production of CSA Clinker and Characterization of additive of CSA

The utilization of the various industries by-products was examined about raw materials of CSA high-functional cement such as coal bottom ash, red mud, phosphogypsum and etc. The development of technology was accomplished for energy and CO2 reduction through development of manufacturing technology, the technology of low temperature sintering(100~200°C) than OPC manufacturing process, and replacement and optimum mix condition of CSA main raw materials; bauxite. In order to develop a CSA cement, manufacturing system was established in Danyang plant of the HANIL Cement Co. Ltd. in Korea. About 4,200 ton of low purity lime-based expansion agent CSA(about 16%) was produced 60 ton per hour from September to October, 2014 in HANIL cement kiln.

3.4 Mine backfill Material Crack Generation test of CSA additives

The significant crack generation test results in Figure 11. In case of FA80%-OPC20 Batch, Crack of mixing after 1day did not occurred. But Crack of mixing after 3day occurred total about 183m by volume. In case of FA80%-OPC10%-CSA10% Batch, Crack of mixing after 1day occurred little and Crack of mixing after 3day occurred total about 52m by volume. In case of FA80%-CSA20% Batch, Crack of mixing after 3day occurred total about 36m by volume. As a result CSA addition level is high, it is possible to significantly reduce the crack generation.+

4.Conclusions

In this study, the strength and the expansion of CSA clinker with small amount of cement waste was increased about 30% compared with an existing OPC and the optimum mix was made to utilize mass amount of fly ash up to 90% in total mix. The optimum mix of fly ash and bottom ash together by CSA clinker cement can be solution of the thermal generation henceforth, then the mix of paste backfill method that is able to handle mass amount of ash was developed to the materials that can fill abandoned mine and underground cavern safely.

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[7] **Table 1** Overview of Ash production from Coal Power Plants.
[8] **Table 2** XRD analysis result of Fly Ash.
[9] **Table 3** XRD analysis result of Fly Ash
[10] **Table 4** Abandoned mine backfill material batch test of OPC 5% blend batch with Fly Ash.
[11] **Table 5** Abandoned mine backfill material batch test of OPC 10% blend batch with Fly Ash.
[12] **Table 6** Abandoned mine backfill material batch test of OPC 5% blend batch with Bottom Ash.
[13] **Table 7** Abandoned mine backfill material batch test of OPC 10% blend batch with Bottom Ash.

Table 1.

Year	**Coal**		**Ash**
	Total imports	**Consumption**	
2004	7,210	4,551	515
2006	7,088	5,020	568
2008	9,047	6,279	710
2010	10,610	7,667	867
2012	11,465	7,913	895

Table 2.

No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	$Ca(OH)_2$	$CaCO_3$	MgO	SO_3
YH_FA	12.13	38.05	49.14	0.00	0.43	0.05	0.08	0.12
YS_FA	20.22	6.70	4.44	16.3	1.5	18.10	2.86	30.01
DH_FA	47.40	32.63	3.32	0.00	0.01	13.47	3.12	0.05

Table 3.

No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	$Ca(OH)_2$	$CaCO_3$	MgO	SO_3
YH_BA	40.25	58.26	0.89	0.00	0.43	0.05	0.08	0.12
TA_BA	33.87	6390	1.67	0.00	0.52	0.04	1.20	0.00
SC_BA	10.30	89.02	0.11	0.00	0.06	0.09	0.02	0.42
YS_BA	23.41	1.42	4.75	21.64	2.76	8.98	0.06	37.03
DH_BA	62.98	32.63	3.32	0.00	0.01	1.01	3.12	0.05

Table 4.

No		Ratio		Sum (%)	Results			
		FA (%)	OPC (%)		W/B (%)	Flow (MM)	Compressive Strength (7days-Mpa)	Compressive Strength (28days-Mpa)
1	YH_FA	95.0	5.0	100.0	37	233	1.9	2.4
2	DH_FA	95.0	5.0	100.0	68	230	4.1	3.9
3	YS_FA	95.0	5.0	100.0	62	228	5.8	6.2

Table 5.

No		Ratio		Sum (%)	Results			
		FA (%)	OPC (%)		W/B (%)	Flow (MM)	Compressive Strength (7days-Mpa)	Compressive Strength (28days-Mpa)
1	YH_FA	90.0	10.0	100.0	37	235	4.8	5.4
2	DH_FA	90.0	10.0	100.0	68	230	5.2	5.0
3	YS_FA	90.0	10.0	100.0	62	230	6.5	8.5

Table 6.

No		Ratio		Sum (%)	Results			
		FA (%)	OPC (%)		W/B (%)	Flow (MM)	Compressive Strength (7days-Mpa)	Compressive Strength (28days-Mpa)
1	YH_BA	95.0	5.0	100.0	30	225	2.3	3.5
2	DH_BA	95.0	5.0	100.0	70	230	-	-
3	YS_BA	95.0	5.0	100.0	54	220	7.5	8.8

Table 7.

No		Ratio		Sum (%)	Results			
		FA (%)	OPC (%)		W/B (%)	Flow (MM)	Compressive Strength (7days-Mpa)	Compressive Strength (28days-Mpa)
1	YH_BA	90.0	10.0	100.0	30	228	4.9	5.2
2	DH_BA	90.0	10.0	100.0	70	232	2.2	1.8
3	YS_BA	90.0	10.0	100.0	54	225	9.2	10.6

Figure Caption

Figure 1 South Korea's future energy plan (2010-2024).
Figure 2 South Korea's power plant Status and coal imports from overseas-2014.
Figure 3 Accidents associated with the limestone mine.
Figure 4 Mine Backfill process of limestone mine.
Figure 5 Flowability test result.
Figure 6 Compressive strength test.
Figure 7 Length changes test.
Figure 8 SEM analysis result of Fly Ash
Figure 9 Shape of Bottom Ash
Figure 10 CSA produced using industrial by products in Hanil Cement Co.Ltd
Figure 11 Crack generation test result.

Figure 1

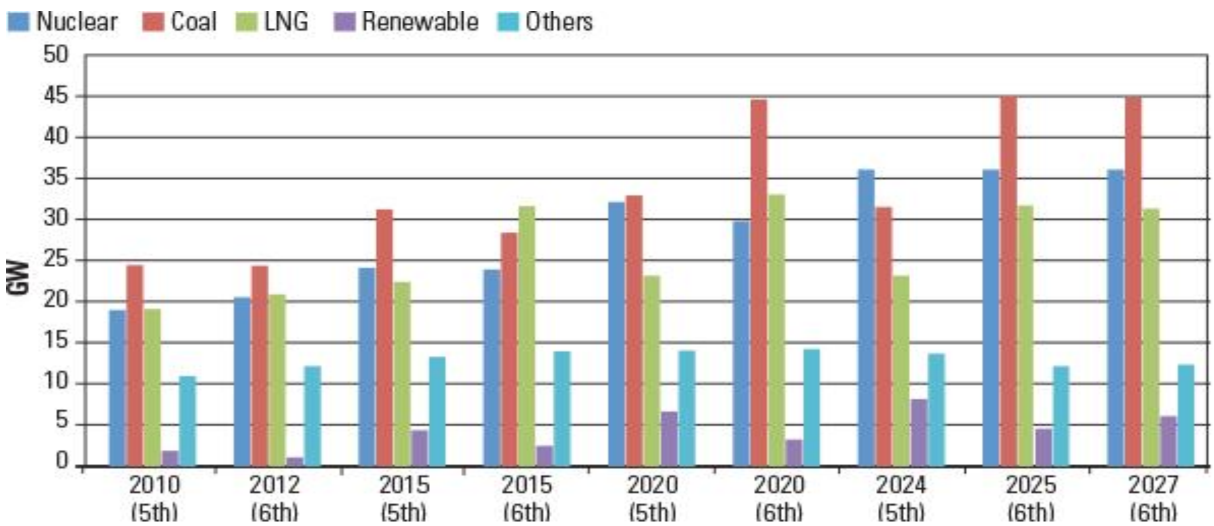


Figure 2

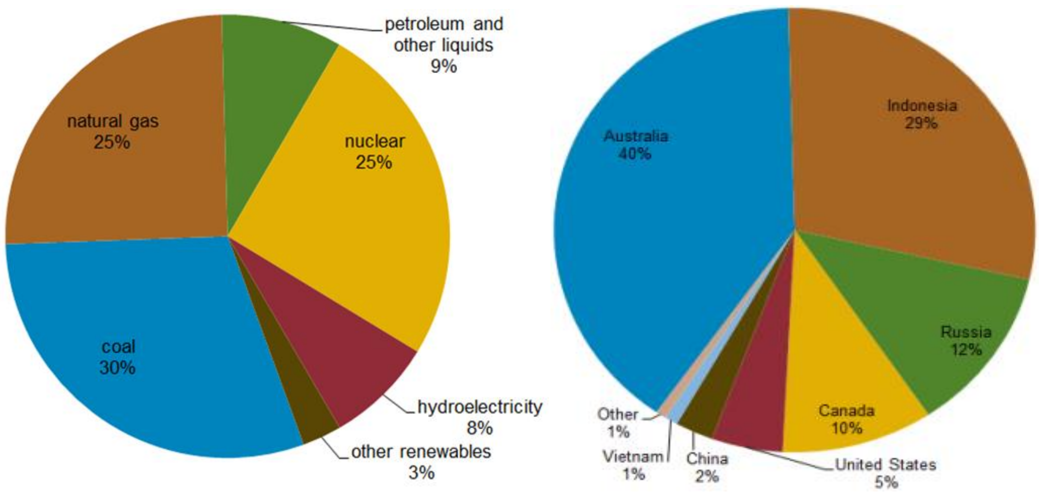


Figure 3

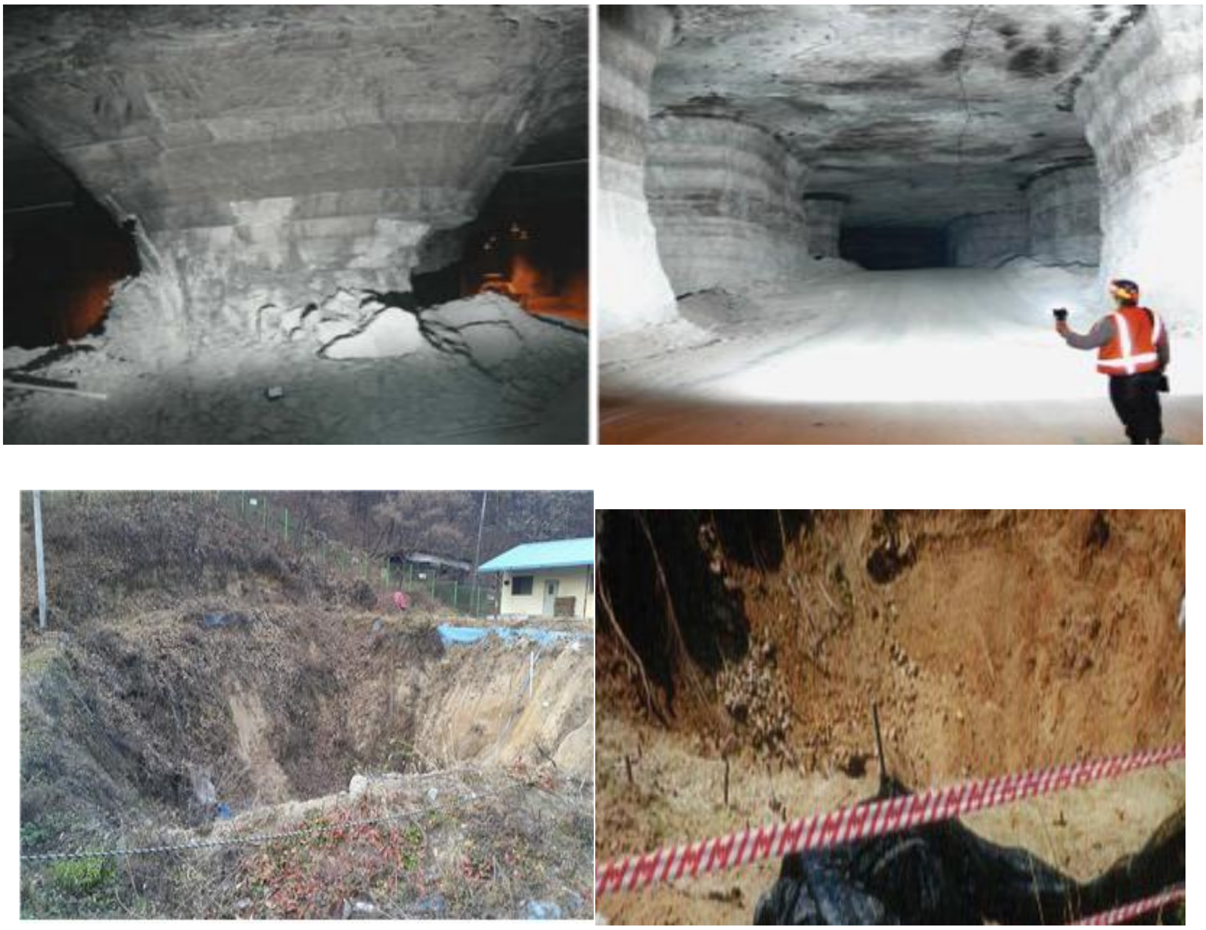


Figure 4

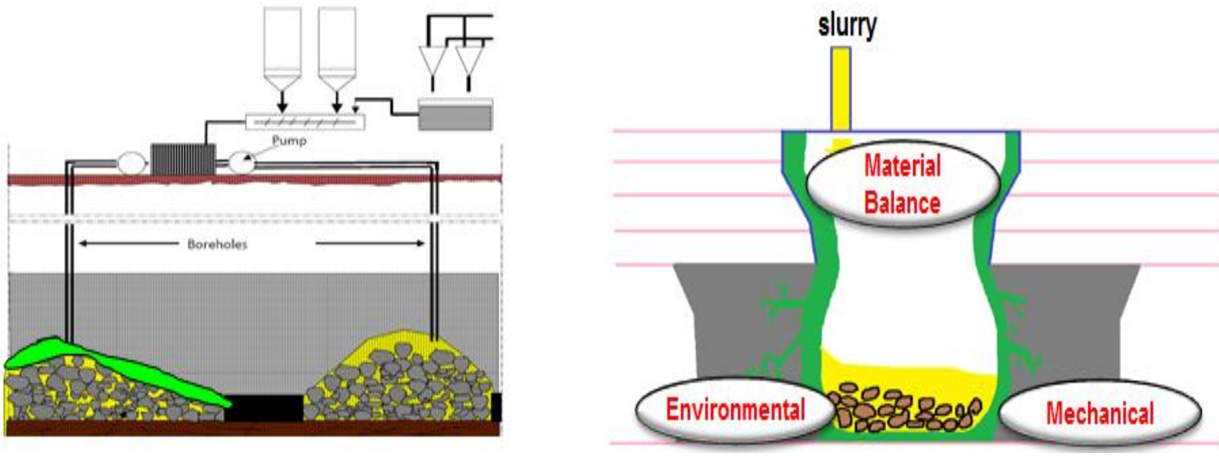


Figure 5

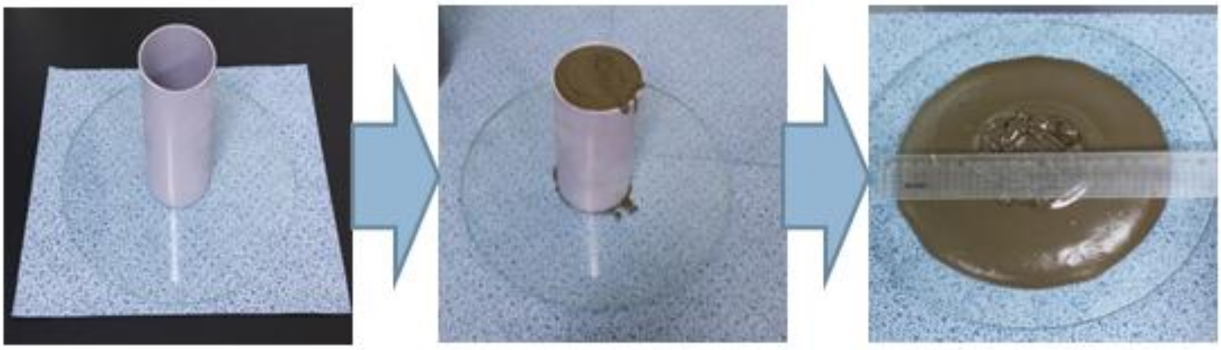


Figure 6

Figure 7

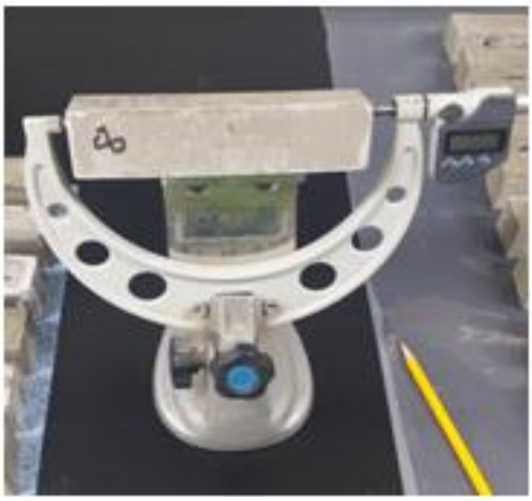


Figure 8

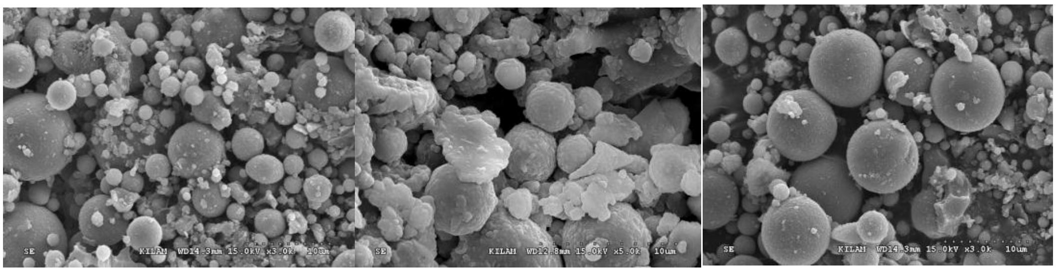


Figure 9

				
YH_BA	TA_BA	SC_BA	YS_BA	DH_BA

Figure 10

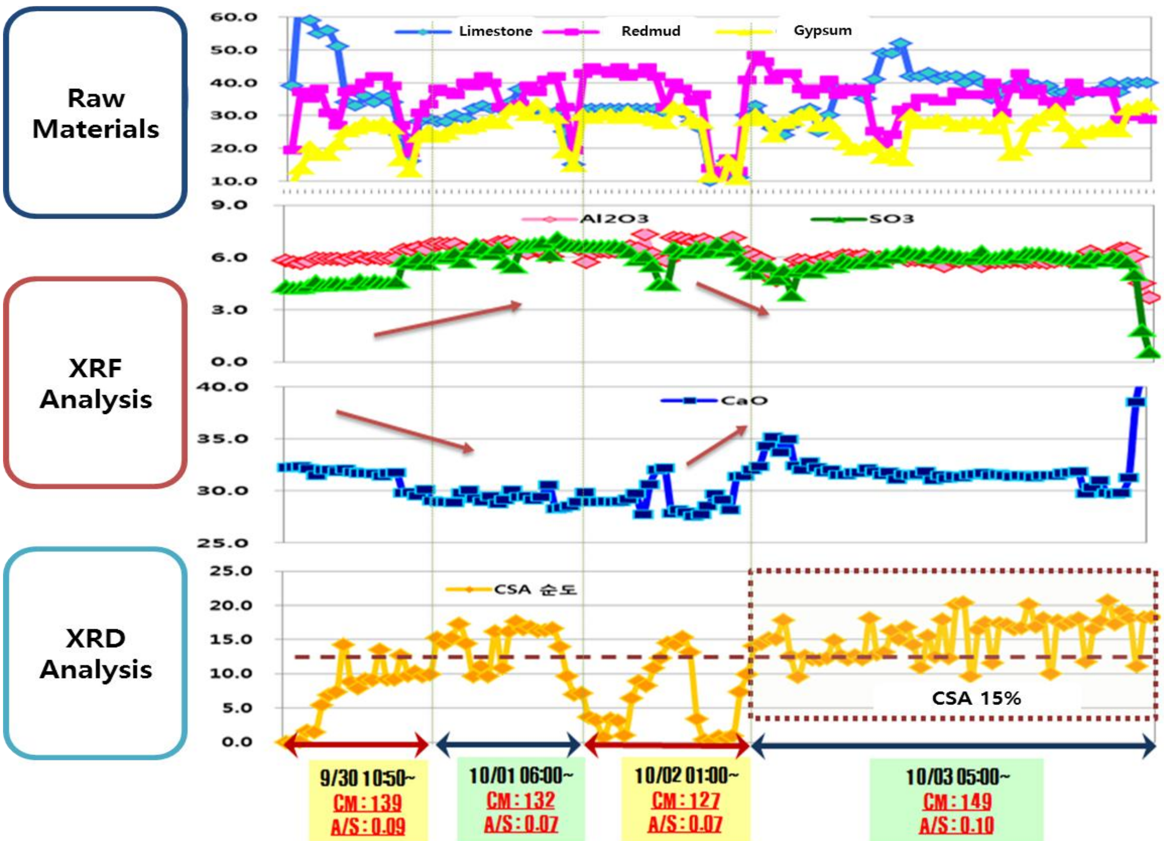
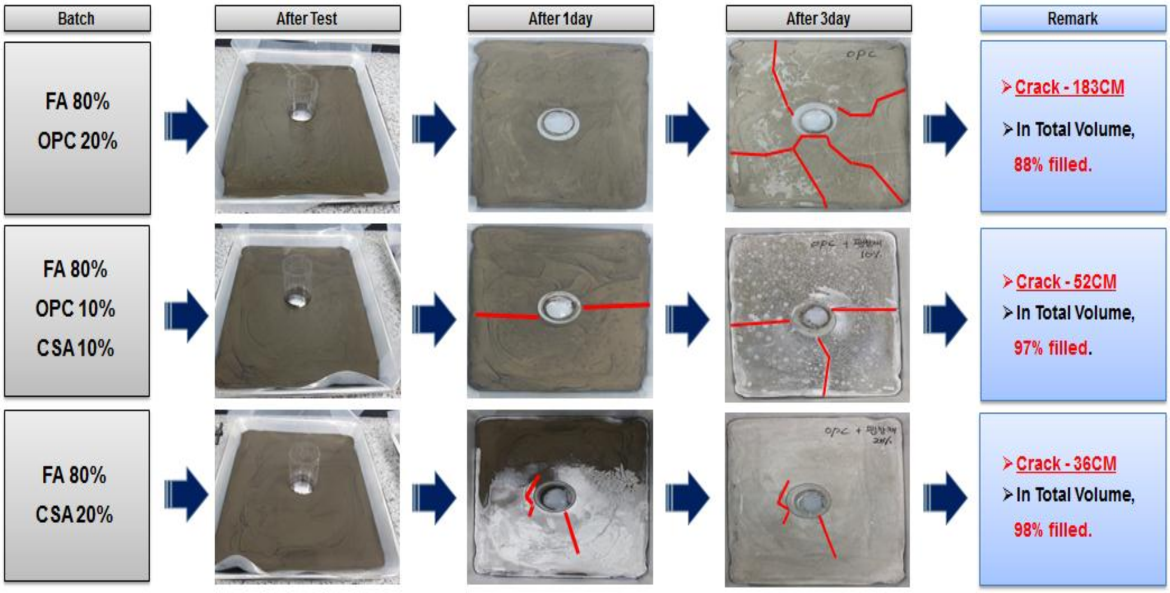


Figure 11


Batch
After Test
After 1day
After 3day
Remark
FA 80%
OPC 20%
➢Crack - 183CM
➢In Total Volume,
88% filled.
FA 80%
OPC 10%
CSA 10%
➢Crack - 52CM
➢In Total Volume,
97% filled.
FA 80%
CSA 20%
➢Crack - 36CM
➢In Total Volume,
98% filled.