Beneficial Utilization of Chinese Dry Flue Gas Desulfurization Materials for Stabilization of Weak Soils

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Presentation Outline

- Project Overview
  - Background
  - Purpose
  - Hypothesis
- Materials
- Methods
- Results
- Conclusions
- Future Work

Project Overview

- Background
  - Wind-deposited soils found in Shanxi Province of China, are not suitable to provide stable subgrade for roadway construction
  - Soils mixed with materials such as lime and coal combustion residuals can create stable subgrades suitable for construction

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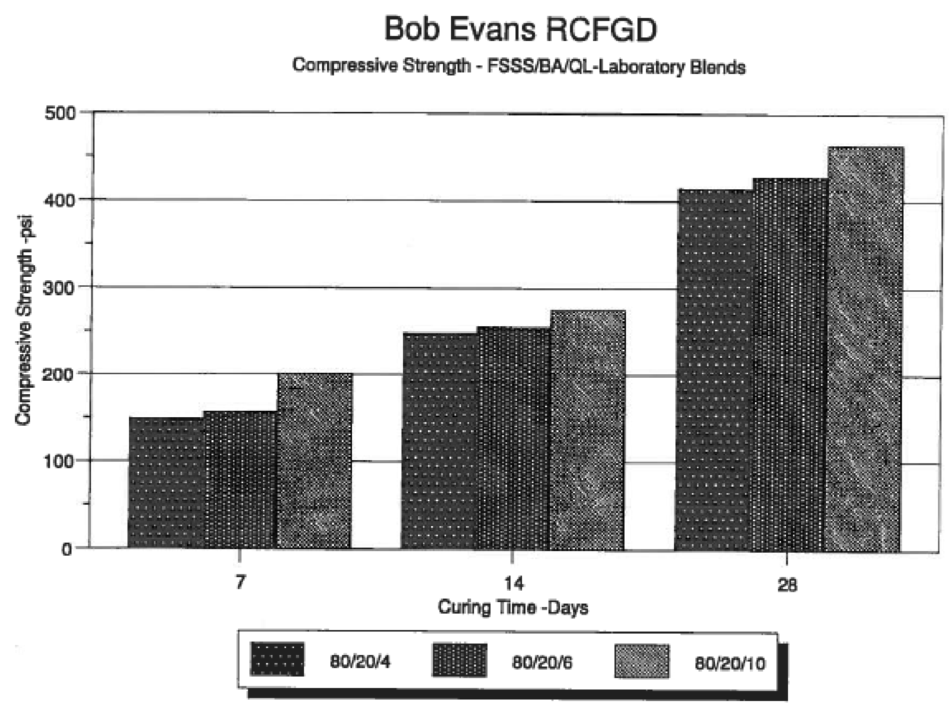
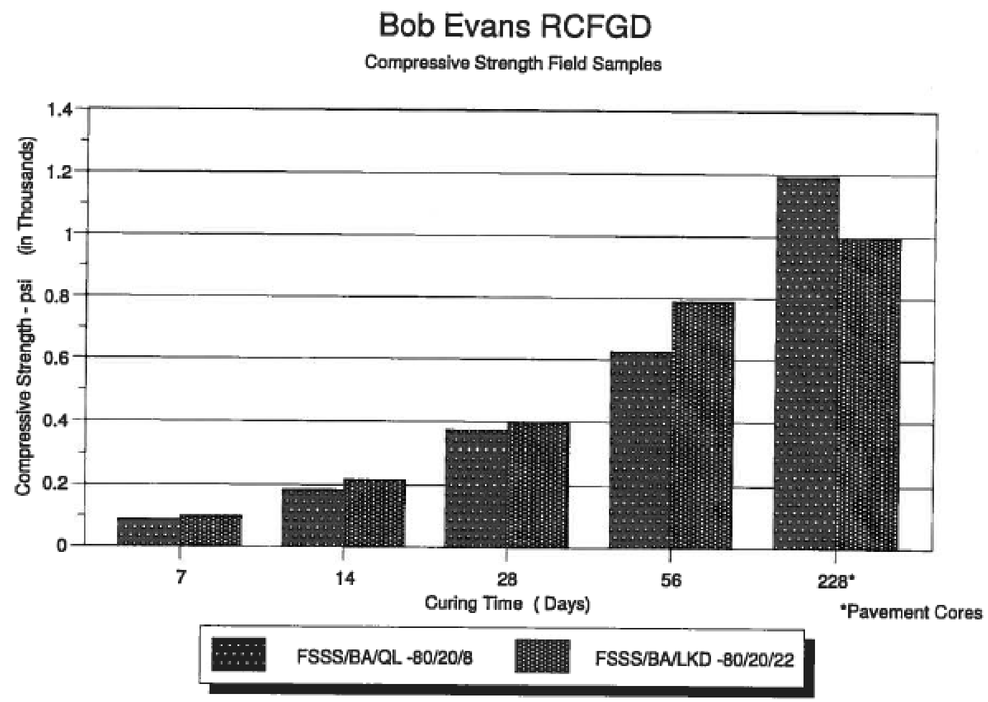
Based on laboratory testing of FGD mixtures, and on the performance of field test sections, Beeghly et al. (1996) concluded that " it is evident that acceptable stabilized base courses can be produced by blending appropriate combinations of fixated FGD material, bottom ash and a chemical reagent. The unconfined compressive strength developed on the mixes with both quicklime and lime kiln dust demonstrates that minimum strengths commonly required for successful stabilized bases were achieved at 28 days. "



After Beeghly et al. 1996



After Beeghly et al. 1996

Project Overview

- Purpose
  - Study stabilization of weak soils using flue gas desulfurization (FGD) material generated in China

- Hypothesis
  - When a certain amount of dry FGD material is added to soil, the soil mix achieves a significant increase in strength over an extended period of time

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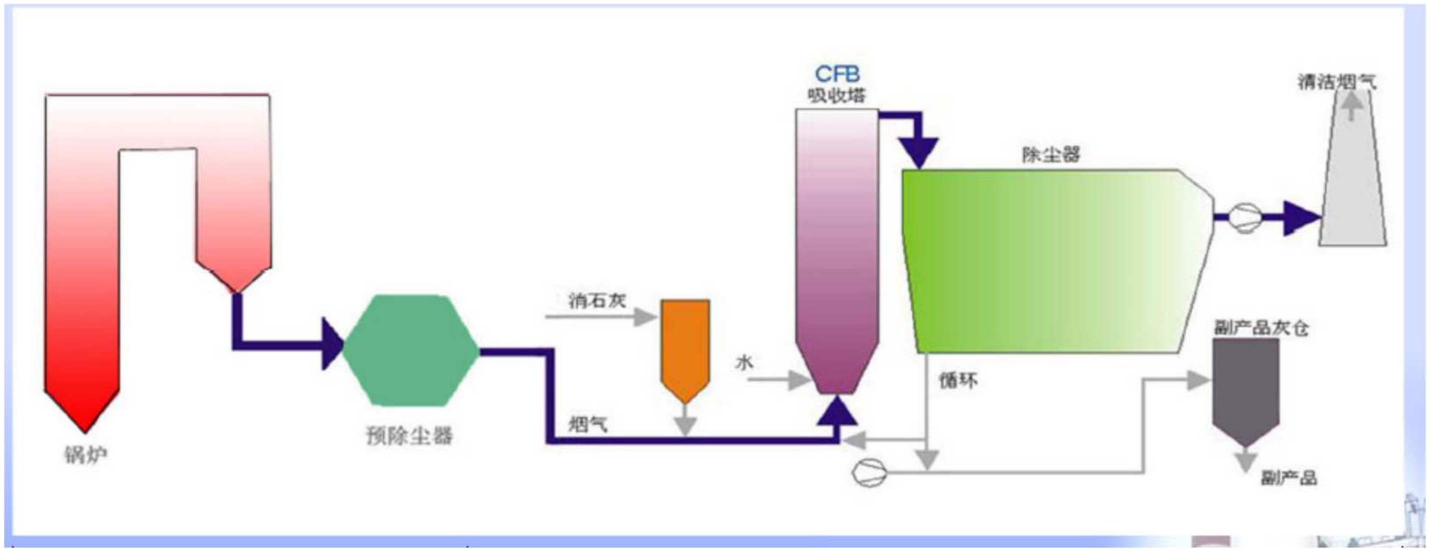
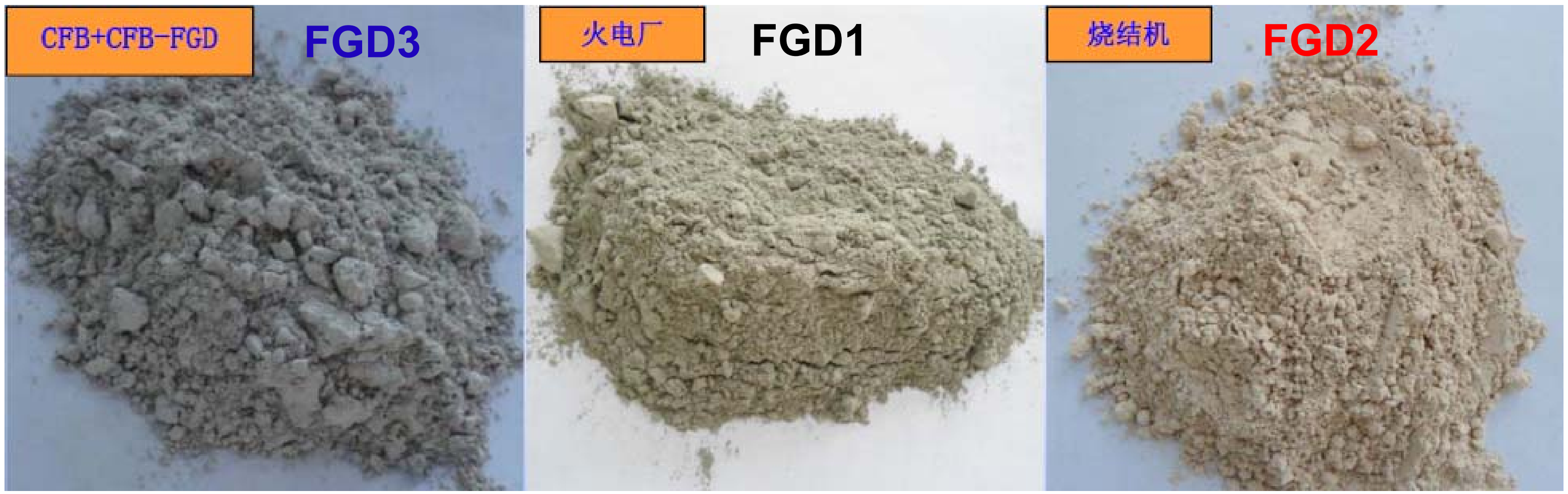
Dry FGD Materials - China

- Coal Combustion Electricity Generation
- Iron and Steel Sintering
- Circulating-Fluidizing-Bed (CFB) Boiler
- Others



Materials

- Liaoyang, LYS1, **FGD1**
  - Coal-fired power plant
- Meshane, MSS2, **FGD2**
  - Iron and steel sintering plant
- CFB+CFB-FGD, S3, **FGD3**
  - Circulating fluidized-bed boiler with FGD polishing unit



Materials

- Control Soil
  - Wind-Blown (Loess) Soil from Indiana
  - Similar characteristics to soil from the Shanxi Province
- Quick Lime
  - Carmeuse
- Fly Ash
  - Class F

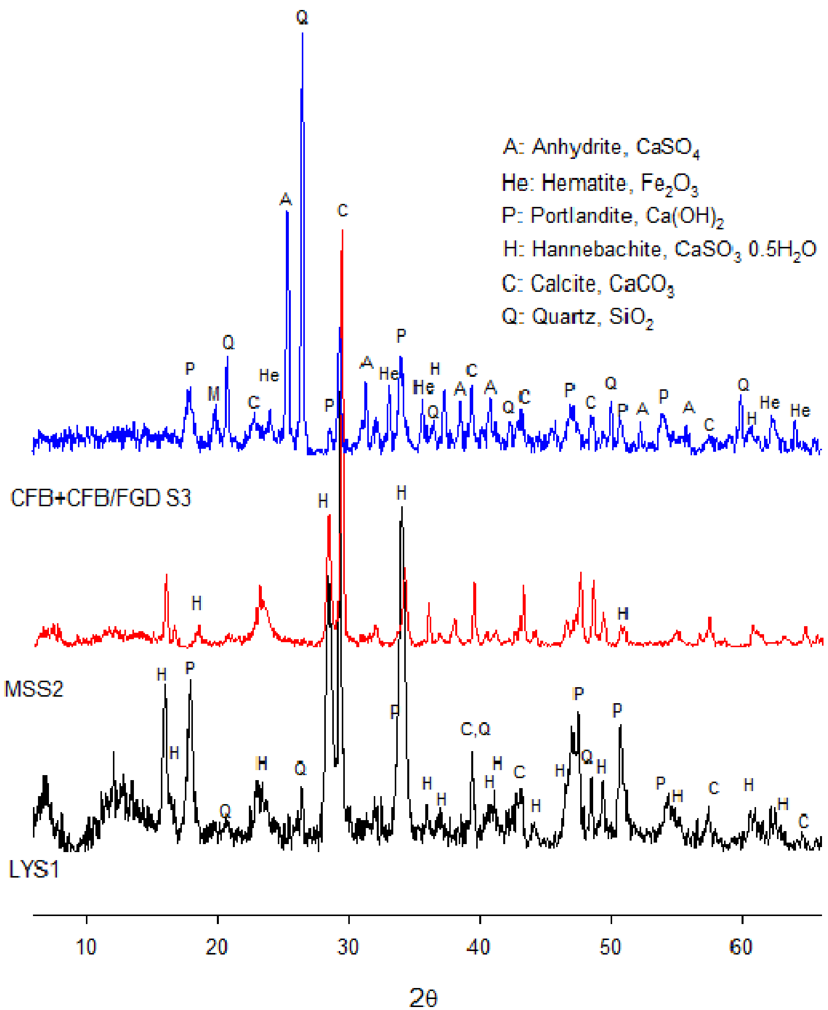
Methods

- Unconfined Compressive Strength Test
  - Samples of soil mixtures created using Harvard Miniature Compaction Apparatus
  - 1 Day, 7 Day, 28 Day, 60 Day Curing Times
  - Three specimens tested at each curing time
- One Dimensional Swell Test
  - Monitored for 200 days before removal
- X-Ray Diffraction
  - Determine mineralogy of mix

Results- Raw FGD Materials

			FGD 1 Liaoyang (LY S1)	FGD 2 Meishane (MS S2)	FGD 3 CFB+CFB-FGD (S3)
Moisture content		%	1.27	3.54	2.10
Mercury	Hg	µg/kg	0.56	4.83	0.70
Phosphorus	P	mg/kg	284	29	323
Potassium	K	mg/g	1.85	1.90	5.46
Calcium	Ca	mg/g	331	313	108
Magnesium	Mg	mg/g	5.82	32.2	5.86
Sulfur	S	mg/g	103	110	22.9
Aluminum	Al	mg/g	6.42	1.63	83.3
Boron	B	mg/kg	89.7	22.5	12.6
Copper	Cu	mg/kg	12.5	45.3	21.6
Iron	Fe	mg/g	4.96	1.45	26.2
Manganese	Mn	mg/kg	133	47	139
Molybdenum	Mo	mg/kg	5.64	1.54	4.12
Sodium	Na	mg/kg	662	797	831
Zinc	Zn	mg/kg	36.0	39.7	65.0
Arsenic	As	mg/kg	10.6	<5	12.4
Barium	Ba	mg/kg	261	181	670
Beryllium	Be	mg/kg	0.85	0.25	4.27
Cadmium	Cd	mg/kg	0.28	4.44	0.95
Cobalt	Co	mg/kg	3.22	0.72	8.63
Chromium	Cr	mg/kg	11.8	3.4	28.9
Lithium	Li	mg/kg	86.1	21.3	548
Nickel	Ni	mg/kg	6.75	0.55	17.8
Lead	Pb	mg/kg	5.4	136	38.3
Antimony	Sb	mg/kg	13.0	9.4	15.4
Selenium	Se	mg/kg	<6.0	14	11.8
Silicon	Si	mg/g	1.84	1.67	3.66
Strontium	Sr	mg/kg	298	195	413
Thallium	Tl	mg/kg	<1.6	<1.6	<1.6
Vanadium	V	mg/kg	21.2	4.11	57.6

Results- Raw FGD Materials



- FGD 1: Liaoyang, LYS1
  - hannebachite, portlandite, quartz, calcite
- FGD 2: Meshane, MSS2
  - hannebachite, calcite
- FGD 3: CFB+CFB-FGD, S3
  - hannebachite, portlandite, quartz, hematite, calcite, anhydrite

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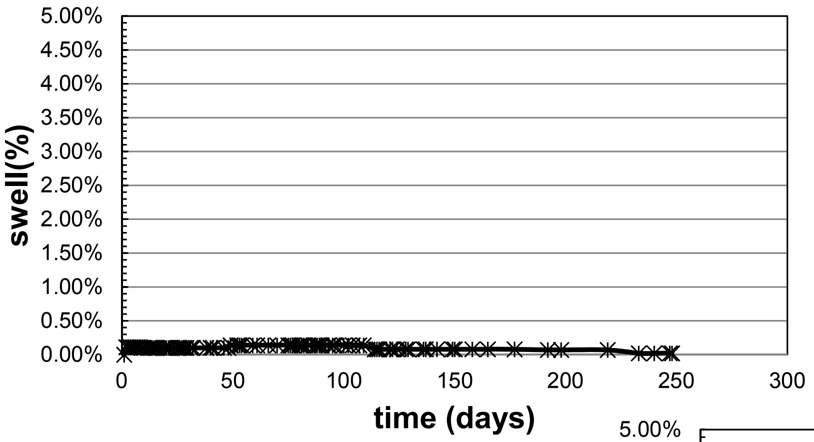
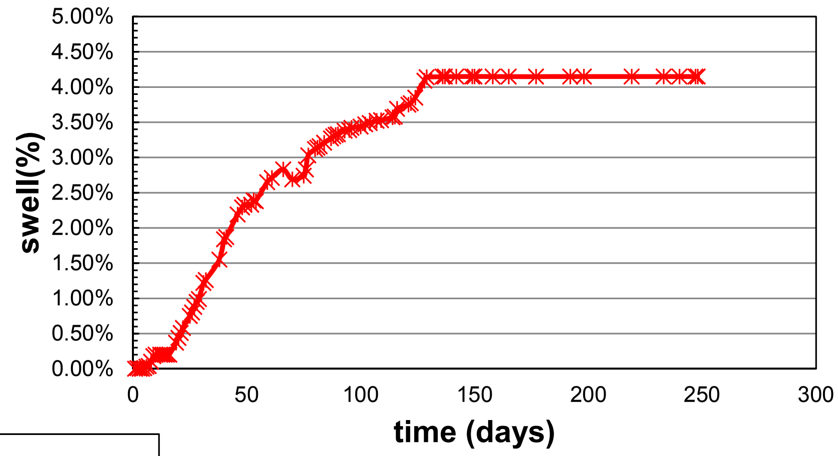
Results- Swell Tests for Raw FGD Materials

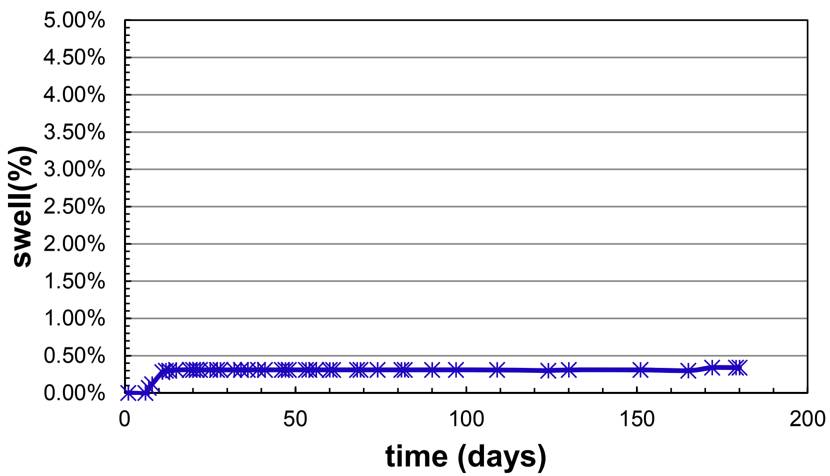
FGD 1 (power plant)



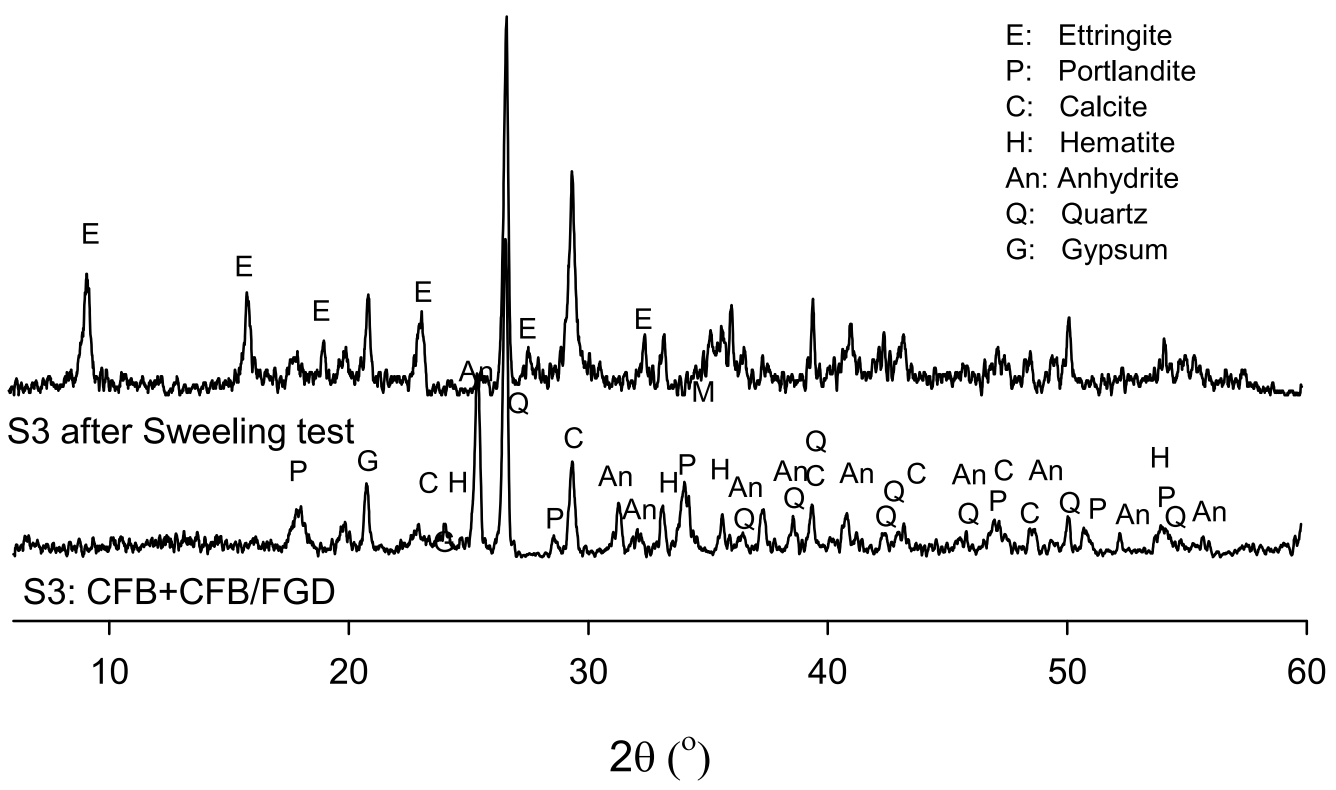
FGD 2 (sintering plant)



FGD 3 (CFB boiler)



Change of Mineral Compositions during Swelling Test for FGD 3



Results- Strength Tests for FGD mixtures

Stabilization Results for 0%FGD

	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Control Soil	25.6	13.2	31.1	8.1	33.9	7.7	37.5	12.9

Stabilization Results for 20%FGD

	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Soil+20%FGD1	34.9	15.6	27.1	15.1	19.4	14.7	18.4	13.5
Soil+20%FGD2	23.5	17.0	27.8	16.5	30.9	16.2	22.7	15.2
Soil+20%FGD3	24.3	16.3	36.7	14.9	46.1	13.8	38.0	15.2

Results- Strength Tests for FGD mixtures

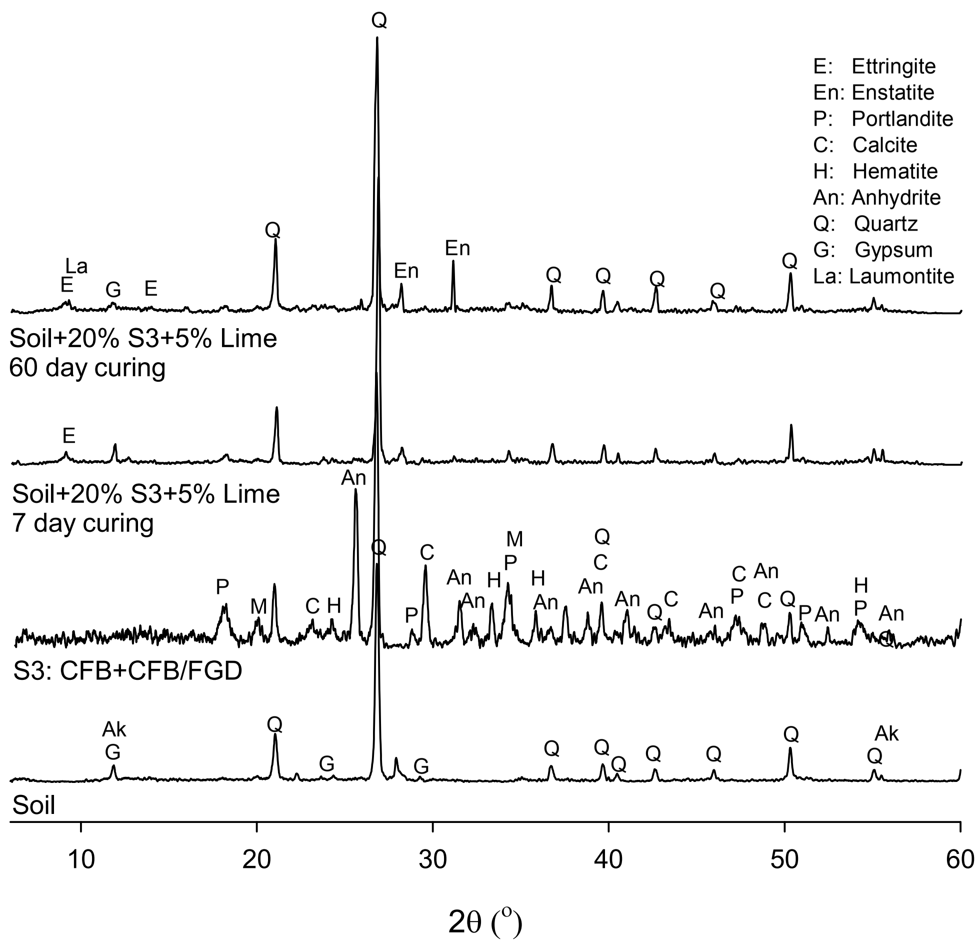
Stabilization Results for 0%FGD

	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Control Soil	25.6	13.2	31.1	8.1	33.9	7.7	37.5	12.9

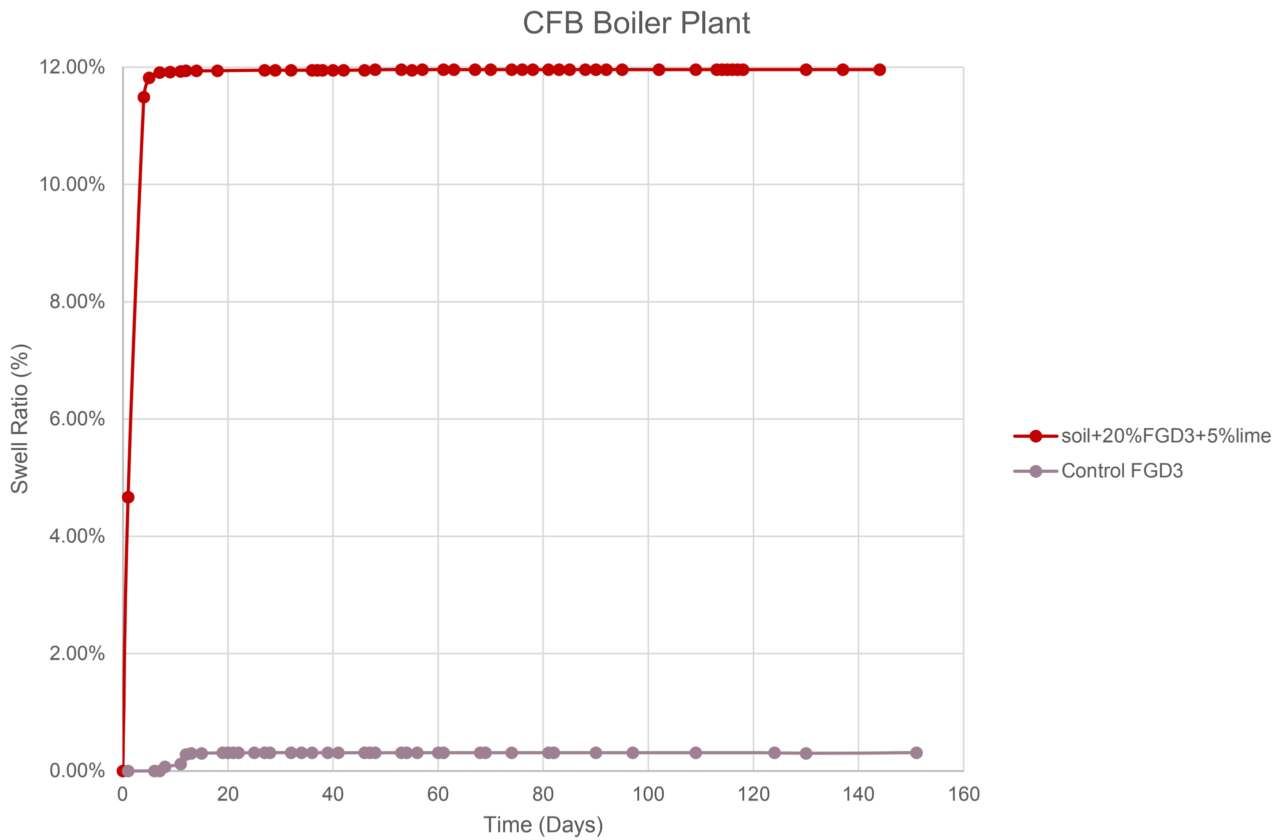
Stabilization Results for 20%FGD and 5%Lime

	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Soil+20%FGD1+5%lime	41.7	14.8	25.2	13.5	22.0	12.8	26.9	13.0
Soil+20%FGD2+5%lime	29.5	13.8	23.9	14.1	13.9	12.7	22.3	13.4
Soil+20%FGD3+5%lime	31.1	13.1	134.9	12.7	256.9	13.1	331.4	12.6

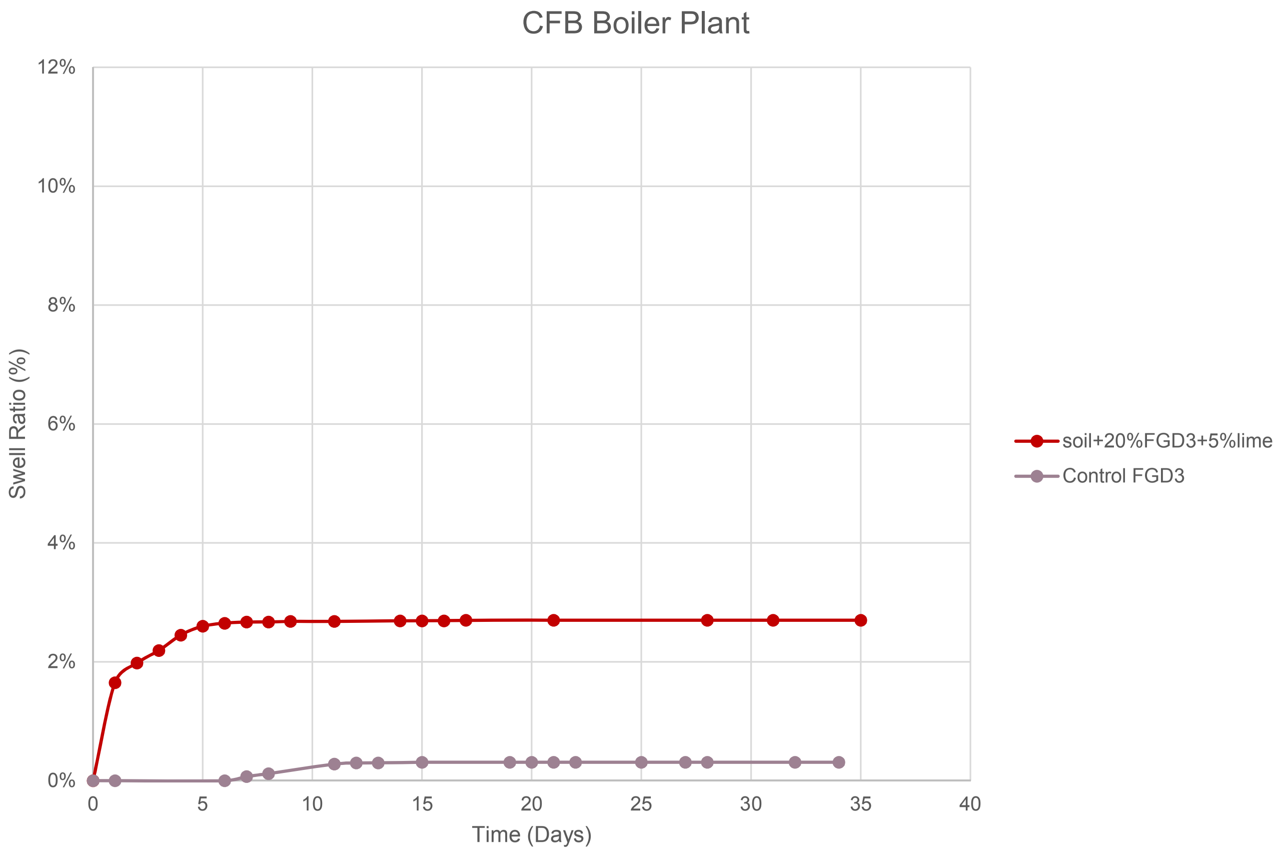
Results- Mineralogy Tests for FGD 3 Mixture



Results- Swell Test for FGD 3 Mixture



Results- Swell Test for FGD 3 Mixture



Results- Strength Tests for FGD mixtures

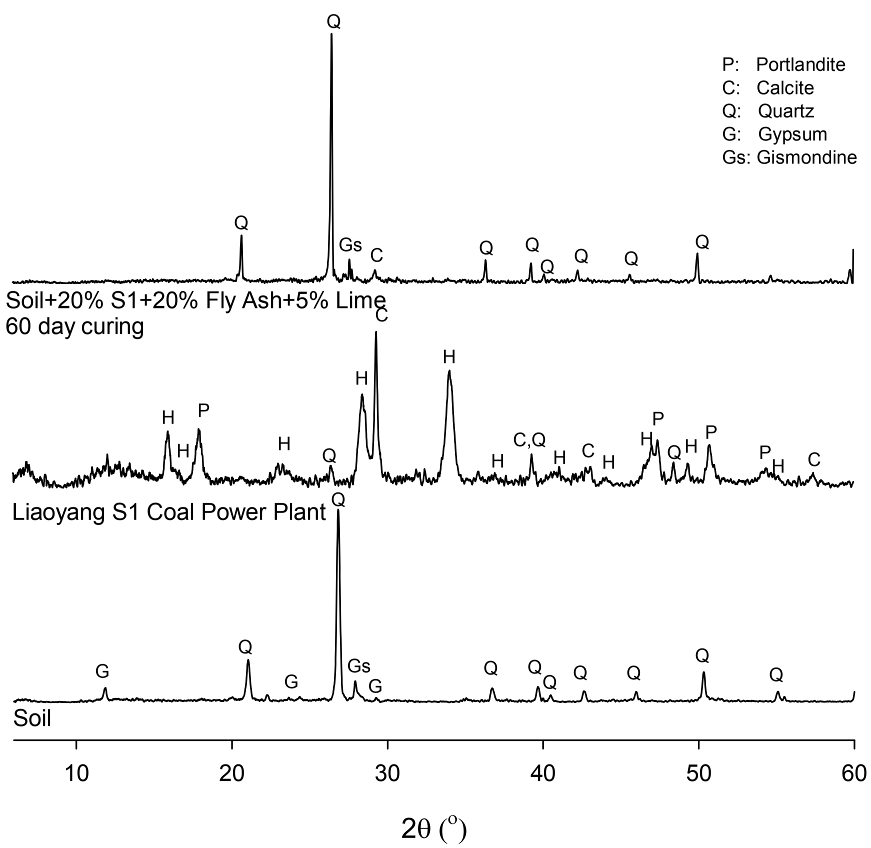
Stabilization Results for 0%FGD

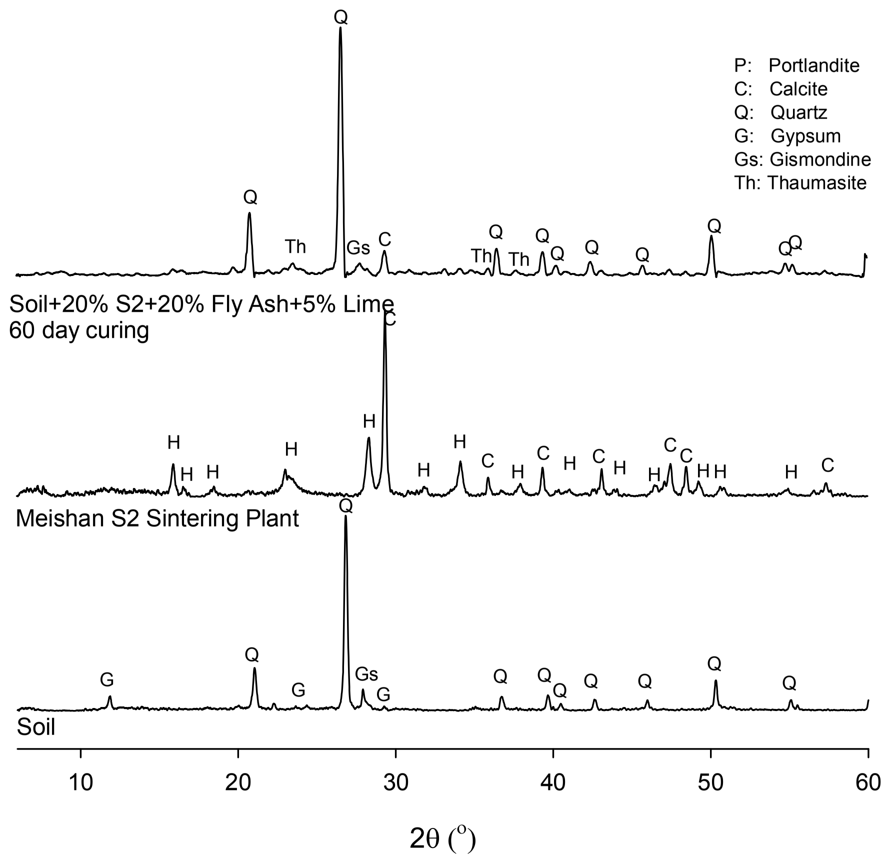
	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Control Soil	25.6	13.2	31.1	8.1	33.9	7.7	37.5	12.9

Stabilization Results for 20%FGD, 20%Ash, and 5%Lime

	1 Day		7 Day		28 Day		60 Day	
	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)	UCS (psi)	Moisture Cont. (%)
Soil+20%FGD1+20%ash+5%lime	28.7	14.8	17.5	12.9	35.9	13.1	37.9	13.0
Soil+20%FGD2+20%ash+5%lime	22.0	15.9	18.6	15.2	51.3	14.7	64.2	14.6

Results- Mineralogy Tests for FGD 1 & 2 Mixtures





Conclusions

- Use of Coal Combustion Residuals such as dry FGD material as a stabilizing agent to improve weak wind-blown subgrades is feasible

- FGD material by itself could not be used to stabilize wind-deposited soils. However, when the mixture is enhanced with the addition of lime, the FGD material and the lime reacts with the soil to obtain a stable soil mass

- Optimum amount of FGD material and lime to be used in the stabilization of the soil is a function of the desired strength characteristics of the soil subgrade.

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Future Work

- Additional Swell Tests for Control Soil and soil+20%FGD3 mixture
- Examine the effects of using hydrated lime versus quick lime with 24 hour mellow period
- Examine methods to reduce swell in FGD2 (Iron and steel sintering plant) using mellow period
- Study stabilized bases (Dry FGD+Lime+Crushed Stone)

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Coal Combustion Products Program

Ohio State's Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.

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Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.

More than 500 animal feeding pads in more than 12 Ohio counties are made from coal combustion products, including feeding pads at The Wilds in Muskingum County.

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