THE USE OF ALTERNATIVE CONSTITUENTS IN CEMENT-BASED SOLIDIFICATION/STABILIZATION OF ELECTRIC ARC FURNACE DUST

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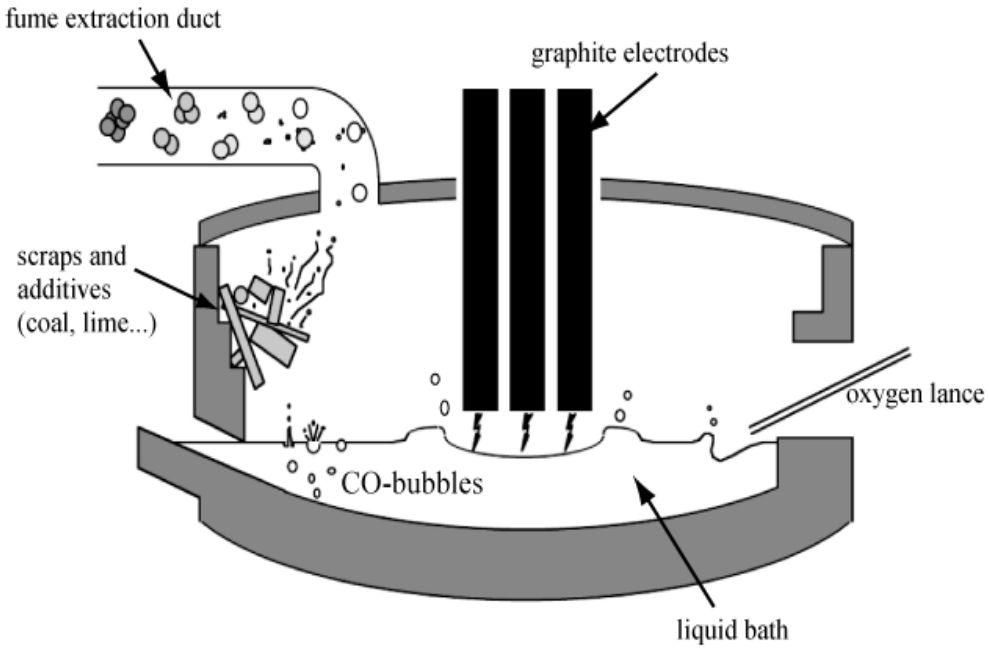
Purpose of this study

- To investigate the potential of using S/S for the treatment of EAFD by using a variety of binders OPC,PFA, steel slag, Hydrated Lime and low-grade MgO.

Electric Arc Furnace Dust (EAFD)

- **Airborne dust generated in the steel manufacturing process when metal scrap is electrically melted.**
- **Classified as hazardous waste because of its heavy metal content mainly Zn,Pb,Cr and Cd.**
- **It is listed in the European Waste Catalogue (EWC,2002) as a hazardous waste with the code of 10 02 07*.**
- **The most common phases found in the EAFD are; franklinite(ZnFe2o4), magnetite(Fe3O4) and zincite(ZnO).**



Source: [Guézennec et al. / Powder Technology 157 (2005) 2 – 11]

*solid wastes from gas treatment containing dangerous substances

MATERIALS

- **Waste-EAFD and CORUS**
  - **CORUS; Europe's second largest steel producer based in UK and is the main provider of EAFD for this study.**

- **BINDERS**

  - **STEEL SLAG**
  - **Supplied by CORUS (<40mm).**
  - **Steel slag, a by-product of steel making produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling.**

  - **HYDRATED LIME and CEMI(supplied by Castle cement)**

  - **Low-grade MgO a by-product of the calcination of natural magnesite**

  - **PFA supplied by UK quality ash association (QAA)**

BINDERS-Composition

	Steel slag	OPC	LG-MgO	PFA	LIME
Compound	(%)	(%)	(%)	(%)	(%)
CaO	35-60	63.78	9.80	1-5	-
SiO_2	9-20	20.33	3.09	45-51	0.35-0.48
Al_2O_3	2-9	4.47	0.38	27-32	0.15-0.25
FeO	15-30	-	-	-	-
MgO	5-15	1.07	65.34	1-4	0.4-0.45
MnO	3-8	-	-	-	-
S	0.08-0.2	-	-	-	0.01-0.014
P	0.01-0.25	-	-	-	-
Cr	0.1-1	-	-	-	-
SO_3	-	3.09	4.14	0.3-1.3	-
Fe_2O_3	-	2.52	2.45	7-11	0.05-0.055
K_2O	-	0.59	-	1-5	-
Na_2O	-	0.22	-	0.8-1.7	-
TiO_2	-	-	-	0.8-1.1	-
Cl	-	0.03	-	0.05-0.15	-
$Ca(OH)_2$	-	-	-	-	97-98
$CaCO_3$	-	-	-	-	0.35-0.75

EAFD-Historical Data-Composition

Oxide	Historical Data (%)	Threshold	Hazardous Properties*
Iron	39.3	No limit	-
Zinc	32.8	0.25%	H14
Calcium	5.8	No limit	-
Manganese	3.5	25%	-
Lead	2.5	0.25%	H5,10,14
Magnesium	3.0	No limit	-
Chromium	0.8	0.1% as Cr(VI)	-
Cadmium	0.02	0.1%	-

*H5 harmful, H10 toxic for reproduction and H14 eco-toxic.

Historical Data-Landfill WAC for EAFD (mg/kg)

Eluate Compliance Limits at L/S = 10 l/kg

Exceeded limits: Molybdenum and Lead

Analyte	EN12457-2	EN12457-3	Hazardous Waste Landfill
As	0.038	0.024	25
Ba	1.2	2.4	300
Cd	0.02	0.02	5.0
Cr	1.1	1.6	70
Cu	2.0	2.5	100
Hg	0.0034	0.0030	2.0
Mo	42	34	30
Ni	0.05	0.05	40
Pb	750	870	50
Se	0.09	0.13	7
Zn	13.0	12.6	200
Cl	12000	11861	25000
F	49	62	500
SO4	10000	11606	50000
Total dissolved solids	46000	49461	100000
Dissolved organic carbon	480	468	1000

METHODOLOGY and WAC Threshold Values

Treatability testing parameters	Proposed Threshold
Consistence BS EN 1015-3	165mm<flow<175mm; no bleeding
Setting time (BS EN 196-3:2005)	2h<initial<8h; final <24h
Compressive strength BS EN 196-1*	> 1 MPa at 28D
pH at 0 acid addition*	11.9<pH<12.2 at 28 D
Acid neutralisation Capacity pH 10 (ANC) DD CEN/TS 15364	Scenario Specific

- Porosity ASTM C 188-95
- Monolithic diffusion test EA NEN 7375
- Granular Leaching Test BS EN 12457-3:2002

(ANC 0 meq/g)

* At 7 and 28 days

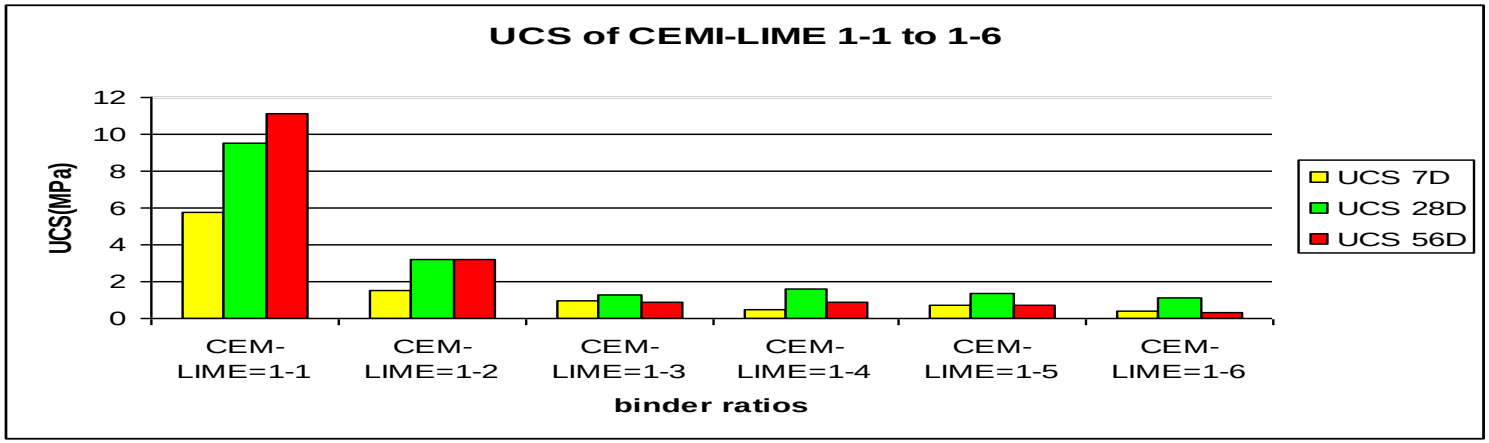
Experimental Programme

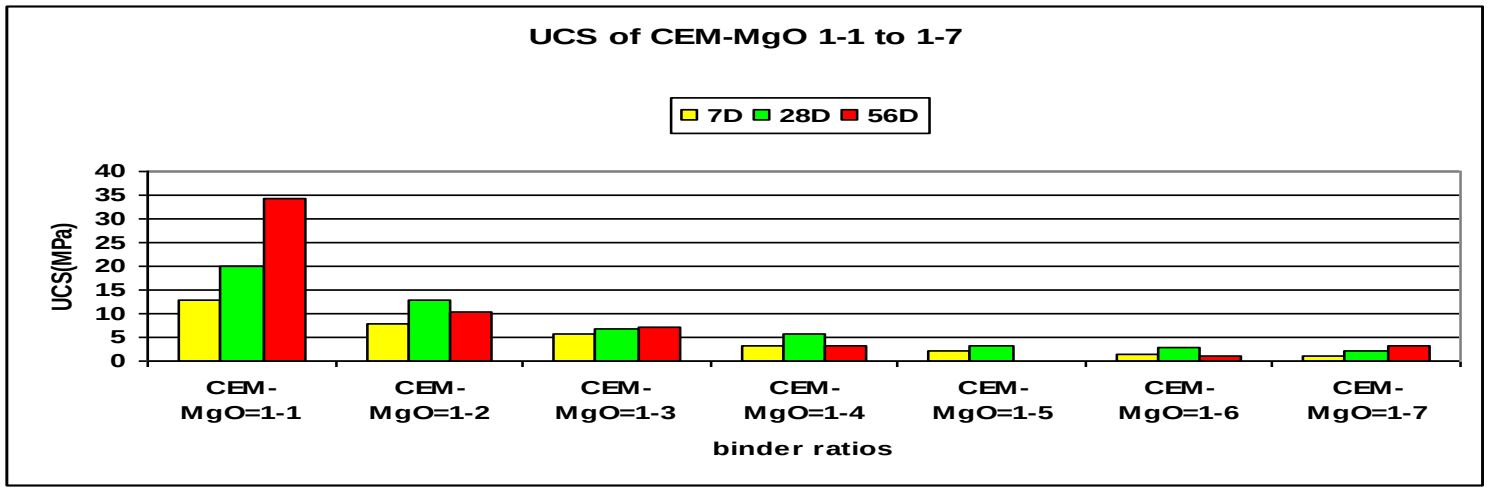
- Screening tests for the following binders mix:
  - CEMI:PFA=1-1 to 1-9(50-50% to 10-90%)
  - CEMI:LG-MgO= 1-1 to 1-7(50-50% to 12.5-87.5%)
  - CEMI:LIME= 1-1 to 1-6(50-50% to 14-86%)
  - CEMI-STEEL SLAG=1-1 to 1-9
  - PFA-MgO= 1-1 ;1-2
  - EAFD at 40%,70% and 90% addition

Moisture content, bulk density and Consistence (with and without EAFD addition

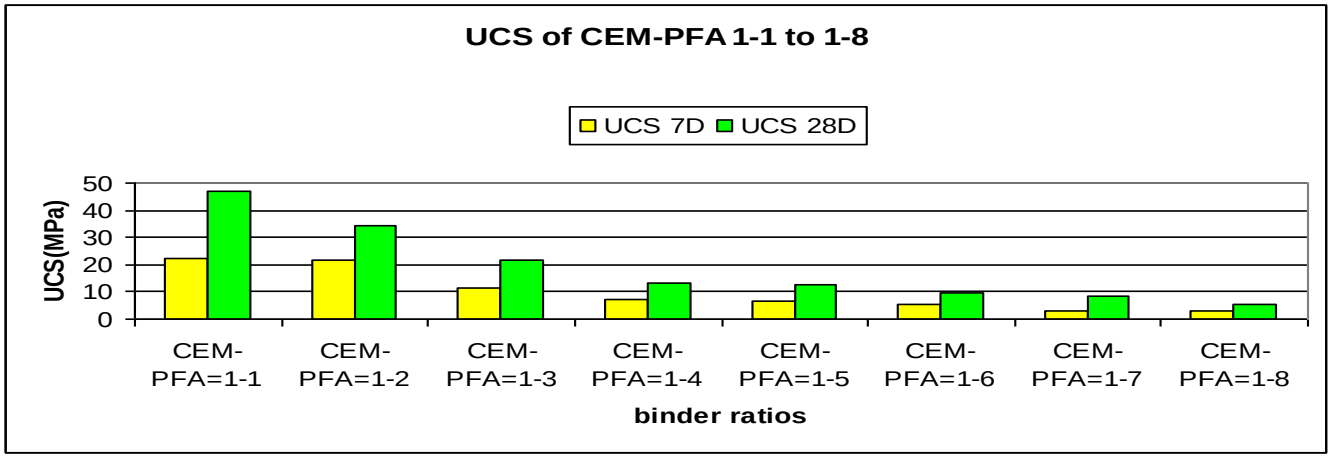
Mix	Water/solid	Bulk density (g/cm3)		Moisture Content ((%)		Consistence (mm)
		7 days	28 days	7 days	28 days	7D+28D
CEM-LIME 1-2	0.6	1.849	1.533	30.6	31.5	195-200
CEMI-LIME=1-2 40% EAFD	.60	1.908	1.612	16.7	31.7	>212
CEM-LIME 1-4*	0.6	1.792	1.528	33.2	33.3	176-188
CEM-MgO 1-2*	0.4	1.837	1.918	9.1	8.8	177-191
CEM-MgO 1-4*	0.45	1.822	1.868	10.6	15.9	191-200
CEM-PFA 1-2	0.20	1.775	1.787	14.7	14.9	188-194
CEMI-PFA=1-2 40% EAFD	0.20	2.008	2.003	9.5	NA	188
CEMI-PFA=1-2 70% EAFD	0.20	2.233	2.332	NA	NA	185-190
CEM-PFA 1-4	0.20	1.687	1.702	18.6	17.9	215
CEMI-PFA=1-4 40% EAFD	0.20	1.927	NA	NA	NA	194-204
CEMI-PFA=1-4 70% EAFD	0.20	2.278	2.062	NA	NA	190
CEM-SLAG1-2	0.15	2.315	2.313	7.9	7.9	190-223
CEMI-SLAG=1-2 40% EAFD	0.15	2.567	NA	4.3	42.8	168-174
CEMI-SLAG=1-2 70% EAFD	0.15	2.503	2.526	7.6	12.7	176
CEM-SLAG 1-4	0.15	2.265	NA	6.7	NA	205
CEMI-SLAG=1-4 40% EAFD	0.15	2.520	2.476	7.0	10.6	174-175
CEMI-SLAG=1-4 70% EAFD	0.2	2.750	2.535	7.0	14.3	178

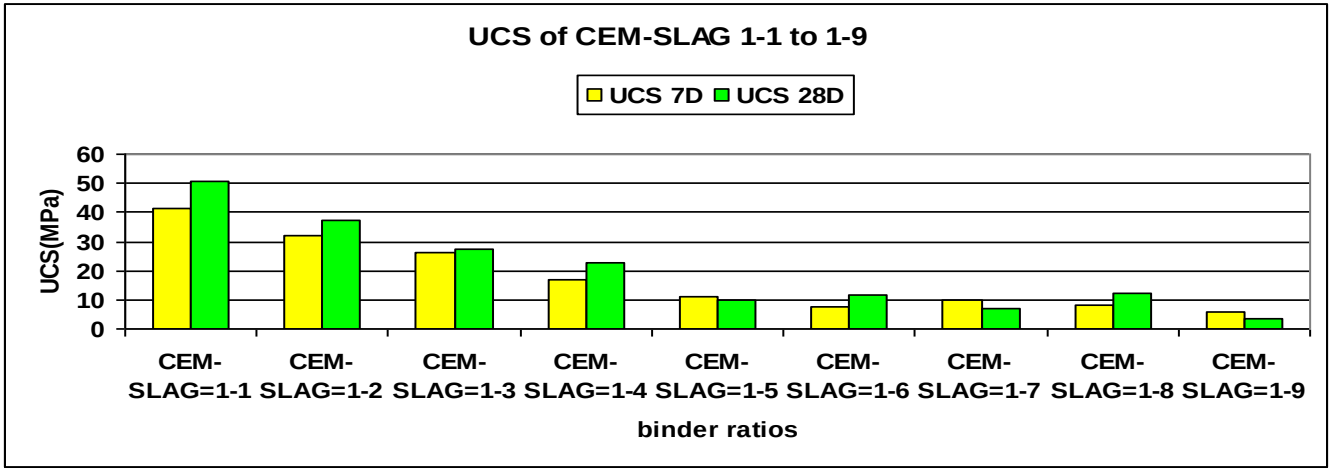
UCS-without EAFD addition



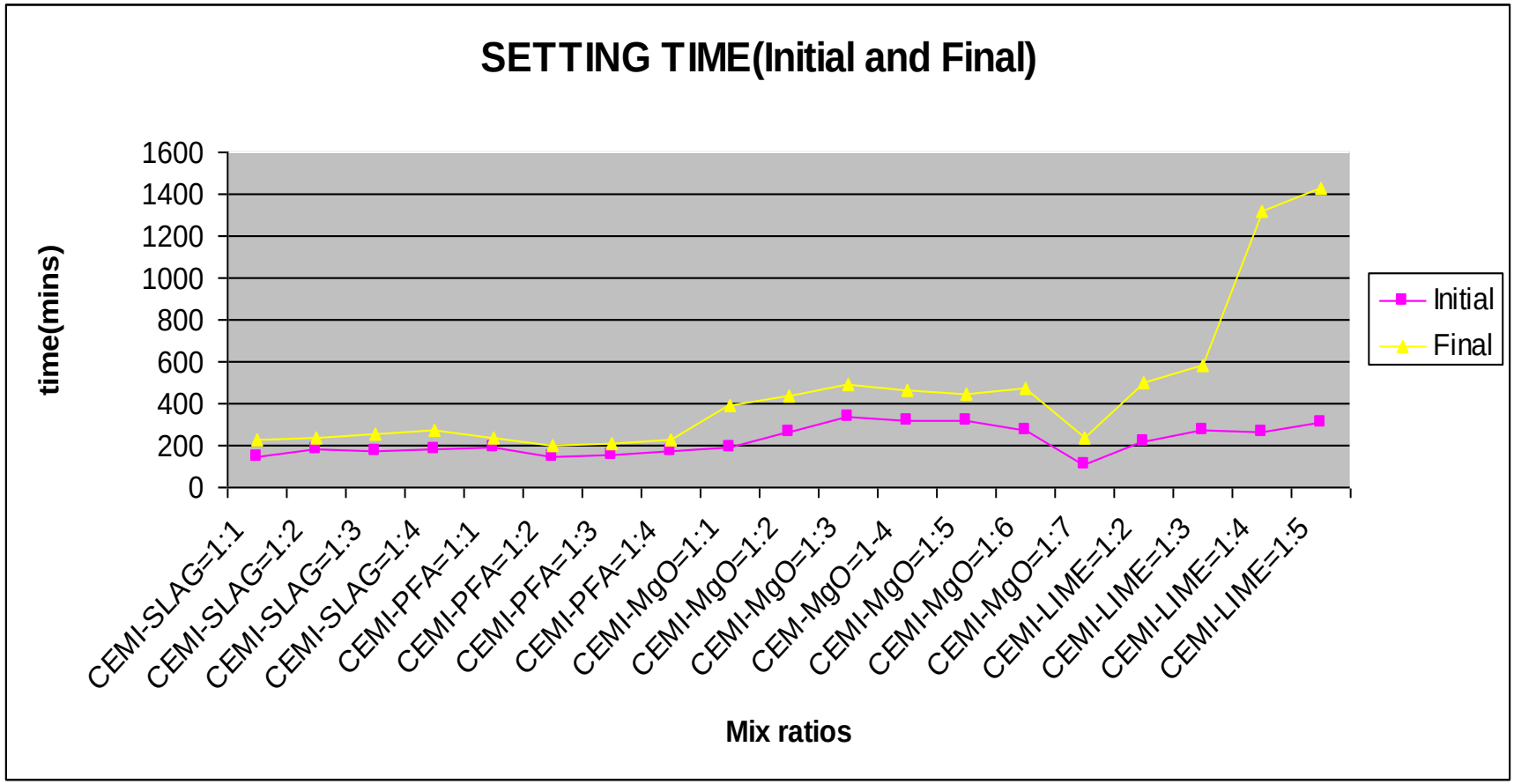


UCS-without EAFD addition

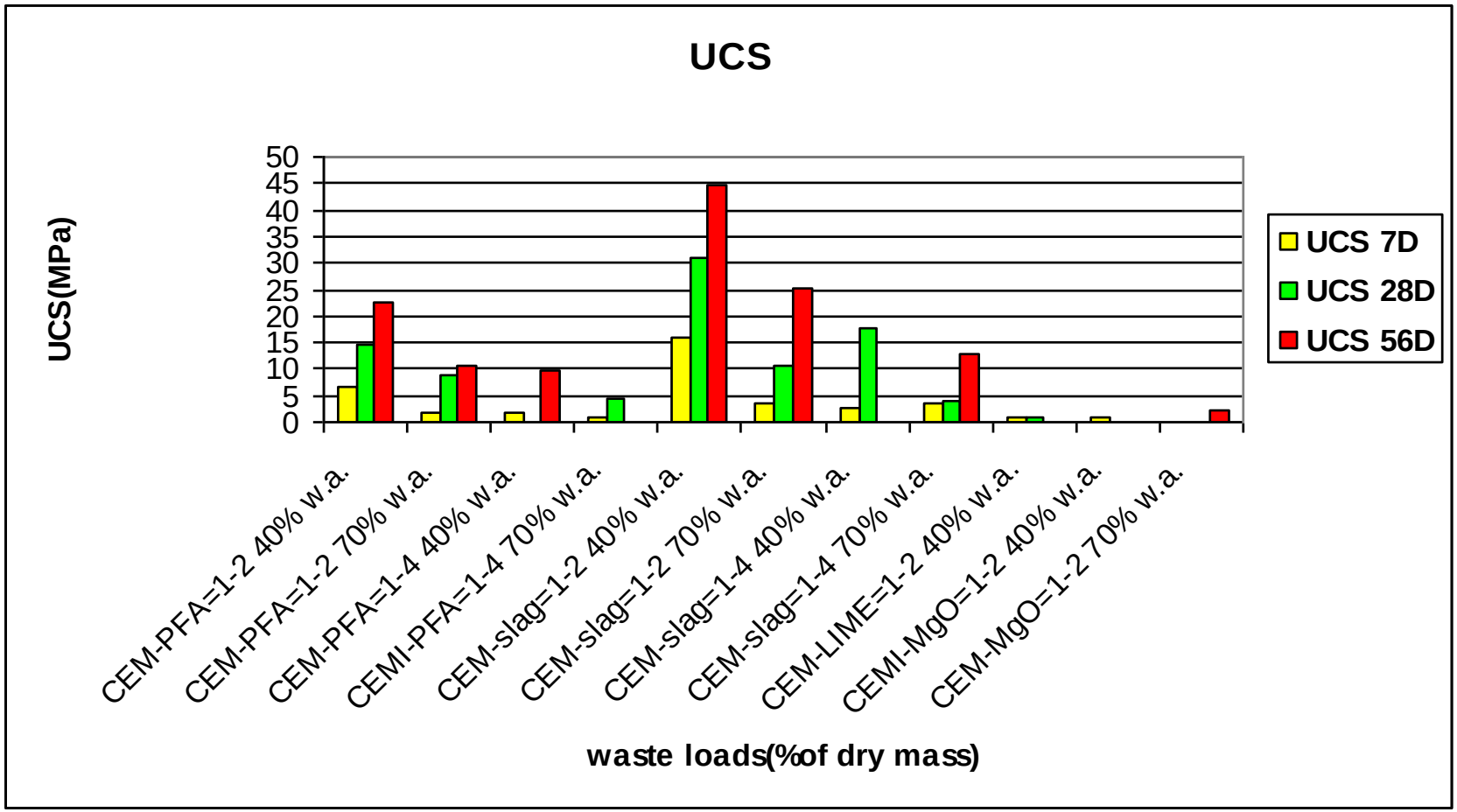




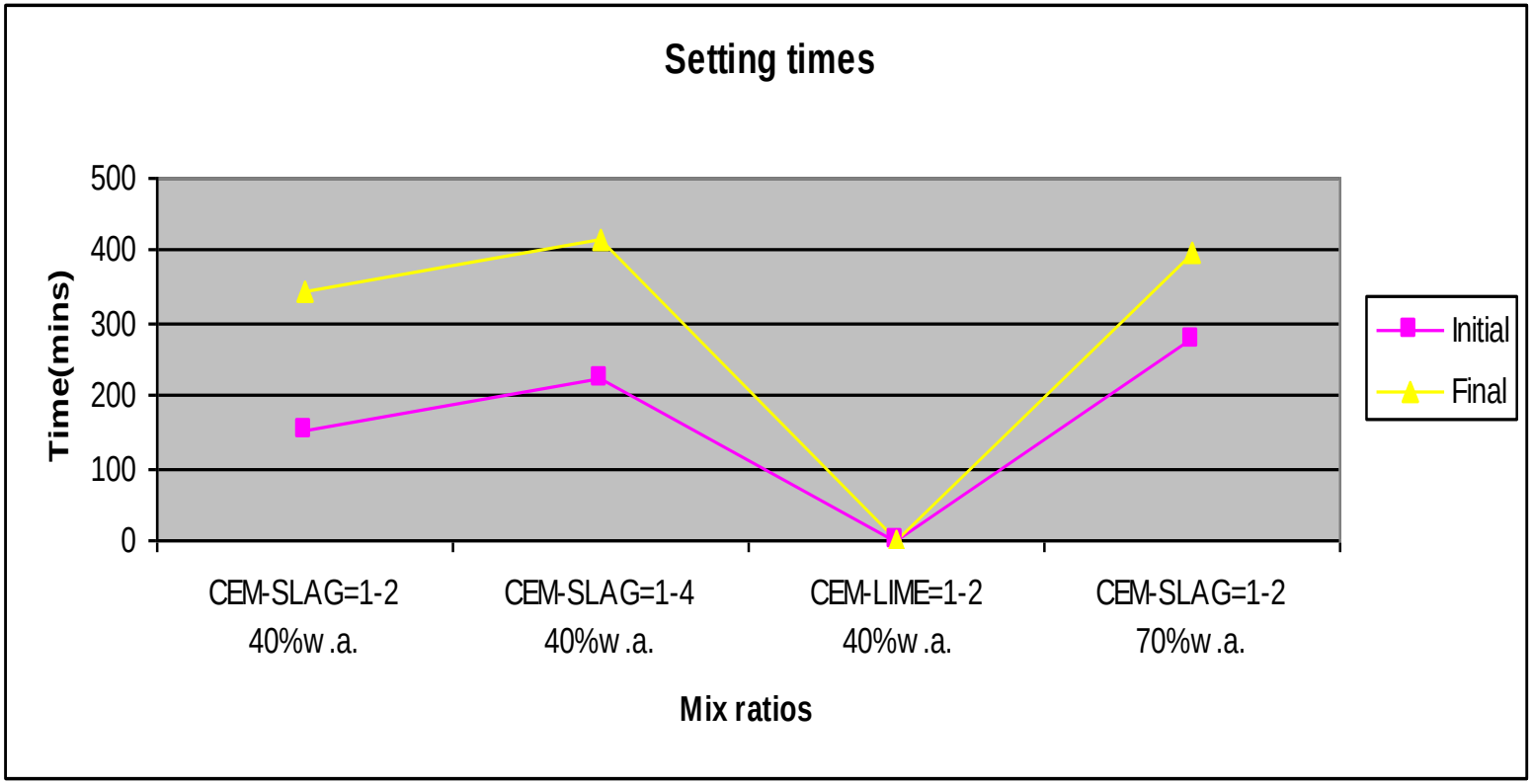
Setting time results-without EAFD addition



UCS Results-with EAFD addition



Setting time results-EAFD addition



Initial ANC Results-
-with and without EAFD addition-

Mix	Age	Acid addition meq/g 0	1	2
CEMI-SLAG=1-2 70% w.a.	7 day	12.32	11.28	10.73
CEMI-SLAG=1-4 70% w.a.	7 day	12.29	11.11	10.07
CEMI-SLAG=1-2 40% w.a.	7 day	12.44	11.74	11.25
CEMI-SLAG=1-4 40% w.a.	7 day	12.38	11.51	10.93
CEMI-PFA=1-2 40% w.a.	7 day	12.37	11.74	11.00
CEMI-LIME=1-2 40% w.a.	7 day	12.48	12.27	12.14

Mix	Age	Acid addition meq/g 0	1	2
CEMI-LIME 1-2	7 day	12.54	12.35	12.24
CEMI-LIME 1-2	28 days	12.38	12.21	12.06
CEMI-LIME 1-4	28 days	12.51	12.3	12.19
CEMI-MgO 1-2	7 day	12.6	12.33	11.64
CEMI-MgO 1-4	7 day	12.37	11.74	11
CEMI-MgO 1-2	28 days	12.38	12.12	11.43
CEMI-SLAG 1-2	7 day	12.6	12.35	12.16
CEMI-SLAG 1-4	7 day	12.47	12.19	NA
CEMI-SLAG 1-2	28 days	12.58	12.31	8.93
CEMI-SLAG 1-4	28 days	12.50	12.25	11.75

*= in progress

Summary –Results

	CEM-LIME			CEM-MgO			CEM-PFA		CEM-SLAG	
Mix	7D	28D	56D	7D	28D	56D	7D	28D	7D	28D
1-1	√(5.8)	√(8.7)	√(11.1)	√(19.7)	√(20.1)	√(34.4)	√(22.3)	√(36.9)	√(41.2)	√(50.7)
1-2	√(1.5)	√(3.2)	√(3.2)	√(8.0)	√(12.9)	√(10.5)	√(21.7)	√(34.4)	√(32.1)	√(37.5)
1-3	√(1.)0	√(1.3)	X(0.9)	√(5.6)	√(9.9)	√(7.1)	√(11.3)	√(21.7)	√(26.0)	√(27.6)
1-4	X(0.5)	√(1.6)	x	√(0.9)	√(7.2)	√(3.3)	√(7.3)	√(13.2)	√(16.9)	√(22.9)
1-5	X(0.7)	√(1.4)	x	√(2.0)	√(3.9)	NA	√(6.(8	√(12.8)	√(10.9)	√(10.0)
1-6	X(0.4)	√(1.1)	x	√(1.4)	√(2.7)	√(1.2)	√ (5.5)	√(9.5)	√(7.3)	√(11.6)
1-7	X(0.3)	x	x	√(1.0)	√(2.3)	√(3.2)	√(3.2)	√(8.7)	√(10.0)	√(7.2)

NA=not available
X= failed
√=succeed

Samples with waste addition

Mix	7D	28D	56D
CEM-PFA=1-2 40% w.a.	√(13.2)	√(14.7)	√(22.7)
CEM-PFA=1-2 70% w.a.	√(1.6)	√(8.9)	√(10.4)
CEM-PFA=1-4 40% w.a.	√(1.9)	NA	√(9.6)
CEM-PFA=1-4 70% w.a.	X(0.9)	√(4.3)	NA
CEM-SLAG=1-2 40% w.a.	√(16.1)	√(31.1)	√(44.5)
CEM-SLAG=1-2 70% w.a.	√(3.6)	√(10.4)	√(25.1)
CEM-SLAG=1-4 40% w.a.	√(2.7)	√(17.6)	NA
CEM-SLAG=1-4 70% w.a.	√(3.5)	√(3.9)	√(12.9)
CEM-LIME= 1-2 40% w.a.	√(0.7)	x	NA
CEM-MgO= 1-2 70% w.a.	x	x	√(2.3)

CONCLUSIONS

- Binder content increases, bulk density decreases and moisture content increases.
- Water/binder ratios affect the consistency and workability of the grouts.
- Waste addition tends to increase bulk density and moisture content.
- Waste addition tends to have a retardation effect and a decrease of UCS.
- PFA, Slag and LG-MgO exhibited potential for the successful S/S of EAFD.
- Leach testing (granular, monolith and ANC) are all currently on-going and the results will provide us with a final picture regarding the successful performance of these solidified products.