

**Long Term Excavatability of Flowable Fill
Containing Coal Combustion Byproducts**

Final Report

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Abstract

Twenty-three different EFF mixtures were placed in trenches simulating utility cuts. Excavation of the trenches was planned for approximately two years after placement, at that time the qualitative excavatability was to be correlated with compressive strength development of the EFF. However, CBRC terminated the project after the first year. All EFF mixtures were tested for flow, unit weight, gravimetric air content, and suitability for load application.

Executive Summary

Twenty-three different EFF mixtures were placed in trenches simulating utility cuts. Excavation of the trenches was planned for approximately two years after placement; at that time the qualitative excavatability was to be correlated with compressive strength development of the EFF. However, CBRC terminated the project after the first year. All EFF mixtures were tested for flow, unit weight, gravimetric air content, and suitability for load application.

Nine EFF mixtures were used to assess the impact of Portland cement content and ASTM C 618 Class F fly ash content. Portland cement contents of 30, 45, and 60 pounds-per-cubic-yard and ASTM C 618 Class F fly ash contents of 300, 370, and 440 pounds-per-cubic-yard were used to evaluate the impact of component proportions. Proportions for the EFF mixtures were chosen using Kentucky Transportation Cabinet and Tennessee Ready Mixed Concrete Association (TRMCA) recommendations as well as a previous Tennessee Technological University research mixture.

Six EFF mixtures were used to assess the impact of Portland cement content and high-unburned carbon fly ash content. Portland cement contents of 45 and 60 pounds-per-cubic-yard and high-unburned carbon fly ash contents of 370, 440, 510 pounds-per-cubic-yard were used to evaluate the impact of component proportions.

The influence of aggregate type on EFF mixtures was evaluated by using five different aggregate types in the EFF mixture recommended by TRMCA (45 pounds-per-cubic-yard Portland cement and 370 pounds-per-cubic-yard ASTM C 618 Class F fly ash). In addition, three comparison EFF mixtures will also be used in the study (1 Tennessee Department of Transportation and 2 air-entrained EFF mixtures).

The results of the research obtained prior to termination of the project by CBRC are presented herein.

Experimental

The EFF mixtures shown in Tables 1 through 4 were evaluated in the study. The proportions of water and aggregate to produce a flow greater than 8.75 inches were determined in the laboratory. The aggregate used for the mixtures in Tables 1 and 2 was river sand. Approximately 5.5 cubic yards of each mixture was delivered to the TTU campus in a ready mix truck. 5.33 cubic yards of each mixture was placed in a 3-foot depth, 3-foot width, and 16-foot length trench. The remainder of the mixture was used to cast compressive strength cylinders and conduct plastic property tests.

Table 1. EFF Mixtures with Type I PC and Class F Fly Ash

Class F Fly Ash	30 lbs/CY PC	45 lbs/CY PC	60 lbs/CY PC
300 lbs/CY	1. KTC Mixture (1)	Mixture 2	Mixture 3
370 lbs/CY	Mixture 4	5. TRMCA Mixture	Mixture 6
440 lbs/Cy	Mixture 7	Mixture 8	9. TTU Mixture (2)

Table 2. EFF Mixtures with Type I PC and High Unburned Carbon Fly Ash

High Carbon Fly Ash	45 lbs/CY Type I PC	60 lbs/CY Type I PC
370 lbs/CY	Mixture 10	Mixture 11
440 lbs/CY	Mixture 12	Mixture 13
510 lbs/CY	Mixture 14	Mixture 15

Table 3. Aggregate Variables for TRMCA EFF Mixture

Aggregate Type / Description	Specification
Mountain Sand (crushed sandstone)	TDOT PCC Fine Agg. – near ASTM C 33 (3)
Manufactured Sand (crushed limestone)	TDOT PCC Fine Agg. – near ASTM C 33
Masonry Sand (high silica dredged sand)	Near ASTM C 144
Screenings (limestone prod. byproduct)	AASHTO M43 Size Number 10 (4)
Oily Foundry Sand*	None
Clayey Foundry Sand*	None

* - Not placed

Table 4. EFF Comparison Mixtures (lbs/CY)

Component	TDOT (5)	MBT MB AE 90	WRG	MBT Rheofill
Type I PC	100	100	100	80
Class F Fly Ash	250 minimum	0	0	0
Aggregate	2800	2439	2316	2501
Water	500	340	270	375
Air Generator	None	70 oz. MB AE 90	3 oz Darafill	1 bag Rheofill

Each mixture was sampled in accordance with ASTM D 5791 Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material (6). The unit weight and air content of each mixture were determined in accordance with ASTM D 6023 Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low Strength Material (CLSM) (7). The consistency of each mixture was determined as per ASTM D 6103 Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM) (8). Fifty 4-inch diameter, 8-inch height, compressive strength cylinders of each mixture were cast in accordance with ASTM D 4832-95 Standard Test Method for Preparation and Testing of Soil-Cement Slurry Test Cylinders with the following exceptions (9):

- Cardboard molds were used rather than plastic due to stripping difficulties with CLSM in plastic molds;
- CLSM were not be mounded on top of the cylinder in the plastic state and removed after hardening with a wire brush due to the high potential for cylinder damage.

Three compressive strength cylinders were tested at each time shown in Table 5, providing that sufficient cylinders survived transportation and mold stripping. Fifty cylinders were made from each EFF mixture and only 39 are required. The compressive strength testing was conducted in accordance with ASTM D 4832-95 Standard Test Method for Preparation and Testing of Soil-Cement Slurry Test Cylinders with the following exception. Compressive strength cylinders were capped with wet-suit neoprene in rigid retaining caps as described in Sauter and Crouch (2). The research described in the paper indicates that the recommended capping technique yields more realistic compressive strengths than the ASTM D 4832-95 approved methods. In addition, the recommended method is either statistically or logistically superior (in most cases both) to the ASTM D 4832-95 approved capping methods.

Table 5. Testing Times

Days	7	28	63	98	140	182	238	301	364	455	546	637	728
Weeks	1	4	9	14	20	26	34	43	52	65	78	91	104
Years						0.5			1	1.25	1.5	1.75	2

Project terminated by CBRC prior to reaching these test dates

The EFF trenches were tested for suitability for load application at approximately 6 hours after placement and subsequently every 2 to 4 hours during regular work hours until each mixture passed the test or 4 days elapsed. The test was conducted as prescribed in ASTM D 6024 Standard Test Method for Ball Drop on Controlled Low Strength Material (CLSM) To Determine Suitability for Load Application (10).

Results and Discussion

Project results are shown in Tables 6 and 7. The following series of statements help explain project chronology.

- Trench excavation and placement began 3/12/01. Five trenches were placed before rain caused the site to become inaccessible
- Trench excavation and EFF placement resumed 5/14/01. Six project trenches were placed on 5/14/01. Nine project trenches were placed on 5/15/01. Three project trenches were placed on 5/16/01.
- EFF mixtures 20 and 21 were not placed in trenches. The foundry sand aggregate for Mixture 20 could not be obtained although repeated attempts were made to obtain it. The aggregate for Mixture 21 was delivered to a local concrete producer. However, the aggregate contained large metal fragments and the concrete producers refused to allow the material in their trucks fearing damage to their mixers. One additional EFF comparison mixture was obtained to partially replace the lost mixtures.

The project was terminated by CBRC prior to reaching the analysis phase. Therefore, no analysis of results was conducted.

Table 6. EFF Mixture Components (lbs/CY) and Plastic Properties

Mixture	Date Placed	PC	Fly Ash	Aggregate	Flow (“)	Ball Drop (hrs)	Air (%)	Unit Weight (pcf)
1 KTC	3/12/01	30	300F	3000	Shear	22	0	131.8
2	3/12/01	30	370F	2560	Shear	21	0	135
3	3/12/01	30	440F	2508	9.5	21	0	132.3
4	3/12/01	45	300F	2603	10.5	20	0	131.6
5 TRMCA	3/12/01	45	370F	2552	11	19	0	131
6	5/14/01	45	440F	2499	11	20	7	121.8
7	5/16/01	60	300F	2595	Shear	19	0	130
8	5/16/01	60	370F	2538	Shear	18	0	131.8
9 TTU CAP	5/16/01	60	440F	2492	18	19	0	131.6
10	5/15/01	45	370H	2697	Shear	19	2	128.9
11	5/15/01	60	370H	2600	8.5	18	3	126.6
12	5/15/01	45	440H	2557	14	71	2	129.2
13	5/15/01	60	440H	2560	15.5	66	3	127.8
14	5/15/01	45	510H	2527	15	69	3	128.2
15	5/15/01	60	510H	2520	16	66	5	125.8
16	5/14/01	45	370F	2552	11	48	2	132.4
17	5/14/01	45	370F	2362 Mountain Sand	Shear	22	3	122.4
18	5/14/01	45	370F	2190 Masonry Sand	12.5	44	2	121
19	5/14/01	45	370F	2611 Screenings	10.5	23	0	135.2
20	Not Placed	45	370F	Foundry Sand Number 1				
21	Not Placed	45	370F	Foundry Sand Number 2				
22 TDOT	5/14/01	100	250F	2800	Shear	21	5	126
23 MBT MB AE 90	5/15/01	100	0	2439	8.75	46	28.3 25	98.6
24 W. R. G. Darafill	5/15/01	100	0	2316	6.25	20	24.3 21	106.7
25 MBT Rheofill	5/15/01	80	0	2501	7.25	67	25.9 22.25	103.8

Gravimetric

F = Class F Fly Ash

Roll-a-meter

River Sand

H = High Carbon Ash

Limestone Manufactured Sand

Table 7. Average Compressive Strengths (in pounds-per-square-inch)

Mixture	Date Placed	7 days	28 days	63 days	98 days	140 days	182 days	238 days	301 days	364 days
1 KTC	3/12/01	5	6	8	9	9	10	9	8	9
2	3/12/01	6	10	12	15	13	15	13	12	16
3	3/12/01	7	13	20	20	19	21	20	22	20
4	3/12/01	9	20	24	40	37	45	43	45	43
5 TRMCA	3/12/01	8	17	18	21	24	35	39	32	41
6	5/14/01	17	20	37	39	56	65	61	52	45
7	5/16/01	10	17	38	56	66	74	99	79	79
8	5/16/01	17	27	52	60	69	81	86	90	76
9 TTU CAP	5/16/01	28	40	78	108	111	145	126	137	101
10	5/15/01	22	34	45	41	68	83	75	87	74
11	5/15/01	27	41	55	81	108	115	122	144	139
12	5/15/01	12	20	23	24	23	21	30	29	28
13	5/15/01	28	31	47	43	63	50	68	83	63
14	5/15/01	23	29	35	38	54	51	62	59	68
15	5/15/01	47	59	76	89	102	117	127	132	137
16	5/14/01	20	49	64	85	81	83	97	88	106
17	5/14/01	13	24	52	79	79	88	118	126	107
18	5/14/01	19	48	61	72	113	105	108	108	110
19	5/14/01	23	58	83	92	99	105	112	117	134
20	Not Placed									
21	Not Placed									
22 TDOT	5/14/01	21	40	68	98	141	184	177	168	201
23 MBT MB AE 90	5/15/01	11	16	19	22	24	25	39	38	35
24 W. R. Grace Darafill	5/15/01	32	36	45	50	51	73	78	74	79
25 MBT Rheofill	5/15/01	11	17	18	20	24	26	36	42	44

Conclusions

Due to the CBRC terminating the project prior to the analysis phase, no conclusions were drawn.

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