A Look at CO_2 Reduction for Ternary Cementitious Combinations

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Outline

- Background
- Objectives
- Work plan
- Test Factorial
- Cost Savings
- CO_2 Emission Comparisons
- Discussion

Background

- Benefits of ternary mixtures
  - Increased durability and strength
  - Reduced permeability, cost, and CO_2 emissions
- Drawbacks of ternary mixtures
  - Increased chance for incompatibilities
  - Early stiffening or delayed set times

Background

- Wanted to write a specification
- Was told NO
  - Have to complete research on “our” materials
- Was then I learned the first lesson of government work

First Lesson of Government Work

Objectives

- Characterize fresh characteristics of ternary mixtures
- Characterize the hardened characteristics of ternary mixtures
- Determine maximum acceptable substitution limits for ternary applications

Work Plan

- Concrete testing
  - 1 source of each class C and F fly ash, grades 100 and 120 slag, and type I portland cement
  - Slump, unit weight, temperature, air content, compressive and flexural strength, MOE, length change, freeze-thaw durability, and chloride permeability
  - 70ºF for mixtures

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Work Plan

- 500 lbs cement / yd^3
  - Coarse aggregate will be limestone
    - 60/40 ratio of coarse to fine aggregate
    - #57 Stone
  - water/cementitious material ratio: 0.45
  - Use of admixtures
    - air entrainment and water reducers to achieve air content and slump within specifications

Test Factorial

Mixture ID	Type I PC	Class C FA	Class F FA	G100S	G120S
100TI*	100				
80TI-20C*	80	20			
80TI-20F*	80		20		
50TI-50G100S*	50			50	
50TI-50G120S*	50				50
50TI-30G120S-20C	50	20			30
40TI-30G120S-30C	40	30			30
30TI-30G120S-40C	30	40			30
30TI-50G120S-20C	30	20			50
20TI-50G120S-30C	20	30			50
10TI-50G120S-40C	10	40			50
50TI-30G100S-20C	50	20		30	
40TI-30G100S-30C	40	30		30	
30TI-30G100S-40C	30	40		30	
30TI-50G100S-20C	30	20		50	
20TI-50G100S-30C	20	30		50	
10TI-50G100S-40C	10	40		50	
50TI-30G120S-20F	50		20		30
40TI-30G120S-30F	40		30		30
30TI-30G120S-40F	30		40		30
30TI-50G120S-20F	30		20		50
20TI-50G120S-30F	20		30		50
10TI-50G120S-40F	10		40		50
50TI-30G100S-20F	50		20	30	
40TI-30G100S-30F	40		30	30	
30TI-30G100S-40F	30		40	30	
30TI-50G100S-20F	30		20	50	
20TI-50G100S-30F	20		30	50	
10TI-50G100S-40F	10		40	50	
60TI-20C-20F	60	20	20		
40TI-30C-30F	40	30	30		
20TI-40C-40F	20	40	40		

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Cost Savings

- 26 foot wide top
- 10 inches in thickness
- One mile length
  - 475 lbs cementitious/yd^3
- Approximately 1000 tons of binder per mile length of roadway

Cost Savings

Binder	$/Ton
Cement	$120
Class C FA	$40
Class F FA	$50
G100S	$90
G120S	$100

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Cost Savings

Mixture ID	PCC Binder Cost / Mile ($)	Potential Savings
100TI*	$120,755	--
80TI-20C*	$104,654	13.3
80TI-20F*	$106,666	11.7
50TI-50G100S*	$105,660	12.5
50TI-50G120S*	$110,692	8.3
50TI-30G120S-20C	$98,616	18.3
40TI-30G120S-30C	$90,566	25.0
30TI-30G120S-40C	$82,516	31.7
30TI-50G120S-20C	$94,591	21.7
20TI-50G120S-30C	$86,541	28.3
10TI-50G120S-40C	$78,490	35.0
50TI-30G100S-20C	$95,597	20.8
40TI-30G100S-30C	$87,547	27.5
30TI-30G100S-40C	$79,497	34.2
30TI-50G100S-20C	$89,560	25.8
20TI-50G100S-30C	$81,509	32.5
10TI-50G100S-40C	$73,459	39.2
50TI-30G120S-20F	$100,629	16.7
40TI-30G120S-30F	$93,585	22.5
30TI-30G120S-40F	$86,541	28.3
30TI-50G120S-20F	$96,604	20.0
20TI-50G120S-30F	$89,560	25.8
10TI-50G120S-40F	$82,516	31.7
50TI-30G100S-20F	$97,610	19.2
40TI-30G100S-30F	$90,566	25.0
30TI-30G100S-40F	$83,522	30.8
30TI-50G100S-20F	$91,572	24.2
20TI-50G100S-30F	$84,528	30.0
10TI-50G100S-40F	$77,484	35.8
60TI-20C-20F	$90,566	25.0
40TI-30C-30F	$75,472	37.5
20TI-40C-40F	$60,377	50.0

Cost Savings for LA Projects

- Assumptions same as before
- Approximately 192 two lane roadway miles bid in 2007 and 2008 construction seasons

Cost Savings for LA Projects

Mix #	Mixture Design	Estimated cementitious material cost 2007-2008 bid years (2 years)	Savings / mix A ($)	Savings / mix B ($)	Savings / mix C ($)
A	100TI	$30,900,951	--	--	--
B	80TI20C	$26,368,811	$4,532,139	--	--
C	50TI50G120S	$25,750,792	$5,150,158	$618,019	--
1	50TI20C30G120S	$23,278,716	$7,622,235	$3,090,095	$2,472,076
2	40TI30C30G120S	$21,012,647	$9,888,304	$5,356,165	$4,738,146
3	10TI50G120S40F	$17,510,539	$13,390,412	$8,858,273	$8,240,254

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CO_2 Reductions

- Portland cement = 0.92 tons / ton cement
- Grade 100 slag = 0.15 tons / ton slag
- Grade 120 slag = 0.20 tons / ton slag
- Class C fly ash = 0 tons / ton ash
- Class F fly ash = 0 tons / ton ash

CO_2 Reductions

Mixture ID	CO2 (tons)	CO2 Savings (tons)	CO2 Savings (%)
100TI*	926		
80TI-20C*	741	185	20.0
80TI-20F*	741	185	20.0
50TI-50G100S*	538	387	41.8
50TI-50G120S*	564	362	39.1
50TI-30G120S-20C	523	403	43.5
40TI-30G120S-30C	431	495	53.5
30TI-30G120S-40C	338	588	63.5
30TI-50G120S-20C	378	547	59.1
20TI-50G120S-30C	286	640	69.1
10TI-50G120S-40C	193	733	79.1
50TI-30G100S-20C	508	418	45.1
40TI-30G100S-30C	416	510	55.1
30TI-30G100S-40C	323	603	65.1
30TI-50G100S-20C	353	573	61.8
20TI-50G100S-30C	261	665	71.8
10TI-50G100S-40C	168	758	81.8
50TI-30G120S-20F	523	403	43.5
40TI-30G120S-30F	431	495	53.5
30TI-30G120S-40F	338	588	63.5
30TI-50G120S-20F	378	547	59.1
20TI-50G120S-30F	286	640	69.1
10TI-50G120S-40F	193	733	79.1
50TI-30G100S-20F	508	418	45.1
40TI-30G100S-30F	416	510	55.1
30TI-30G100S-40F	323	603	65.1
30TI-50G100S-20F	353	573	61.8
20TI-50G100S-30F	261	665	71.8
10TI-50G100S-40F	168	758	81.8
60TI-20C-20F	555	370	40.0
40TI-30C-30F	370	555	60.0
20TI-40C-40F	185	741	80.0

CO_2 Reductions

- 26 foot wide top
- 10 inches in thickness
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CO_2 Reductions

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Potential CO_2 Reductions in LA

Mix #	Mixture Design	Estimated tons of CO_2 Emissions 2007-2008 bid years (2 years)	CO_2 Savings / mix A (tons)	CO_2 Savings / mix B (tons)	CO_2 Savings / mix C (tons)
A	100TI	176959	--	--	--
B	80TI20C	141605	35354	--	--
C	50TI50G120S	107781	69178	33825	--
1	50TI20C30G120S	97079	79880	44526	10702
2	40TI30C30G120S	79498	97461	62108	28283
3	10TI50G120S40F	36882	140077	104723	70898

Conclusions

- CO_2 reduction can be achieved using ternary cementitious systems
- Great cost savings are also realized in the process
- Better quality more durable concrete

Questions

I'M WORRIED ABOUT GLOBAL WARMING BECAUSE THERE'S NO EASY SOLUTION.
WHAT ABOUT ASPHALT?
ASPHALT?
ROADS. PARKING LOTS. ROOFS. IF ALL THE ASPHALT IN THE WORLD WERE PAINTED WHITE (WHICH REFLECTS HEAT) INSTEAD OF BLACK (WHICH ABSORBS HEAT) THE WORLD WOULD BE MUCH COOLER... PERHAPS EVEN CHILLY.
RRRIGHT.
STILL WORRIED ABOUT GLOBAL WARMING?
NO.
NOW I'M WORRIED ABOUT YOUR BRAIN.
TELL HER ABOUT YOUR ALUMINUM FOIL HAT IDEA...