

Fly ash from Co-combustion of Petroleum Coke and Coal for Use in Concrete Production

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Petroleum Coke Use at Coal- Fired Power Plants

- ◆ **Co-combustion of petcoke with bituminous coal - fuel economics**
 - ◆ **Jacksonville Electric Authority St. Johns River Power Park - Jacksonville, Florida - routinely 20% petcoke / coal blend, up to 30% petcoke**
 - ◆ **NB Power Belledune Station routinely burns 25% petcoke with bituminous coal as a blended fuel**
 - ◆ **Other power plants use smaller proportion of petcoke but use increasing**

Defined Sources of Fly Ash

- ◆ *CSA A3000 - "the finely divided residue that results from the combustion of pulverized coal..."*
- ◆ *ASTM C 618 & AASHTO M 295 "...finely divided residue that results from the combustion of ground or powdered coal..."*
- ◆ *Florida DOT circa 1997 "...fly ash... obtained from the residue of an electric generating plant using only ground or powdered coal."*

Coal/Petcoke ash properties

- ◆ **No experience / data for coal / petcoke ash blends**
 - ◆ **What does petcoke contribute to fly ash?**
 - ◆ **What are the differences in chemical / physical properties of fly ash derived from coal/petcoke blends versus coal only?**
 - ◆ **Are there any differences in concrete produced from coal/petcoke blends?**

Petroleum Coke

- ◆ Petroleum coke (petcoke) - black solid, obtained by cracking and carbonizing residue feedstocks from the distillation of heavier petroleum oils.
- ◆ Practical, less expensive supplemental fuel for pulverized coal fired utility boilers
- ◆ Typical petcoke composition (Dry Basis)
 - ◆ 92-96% Fixed Carbon
 - ◆ 3 - 7 % Sulfur
 - ◆ 0.2 - 1% ash

Fuel at JEA SJRPP

- ◆ JEA - St. Johns River Power Park
 - ◆ Two 660 MW pulverized fuel boilers
 - ◆ Permitted to use up to 30% petcoke as co-fuel with bituminous coal
 - ◆ Flue gas desulfurization units for utilization of high-sulfur fuels - produces gypsum for wallboard
- ◆ 2002
 - ◆ 3,140,000 tons Coal @ 9.1 % Ash Content
 - ◆ 680,000 tons Petcoke @ 0.42 % Ash Content
- ◆ Petcoke 21% of fuel - 0.99% of Ash
- ◆ Reduced fuel ash → high LOI 12-30%



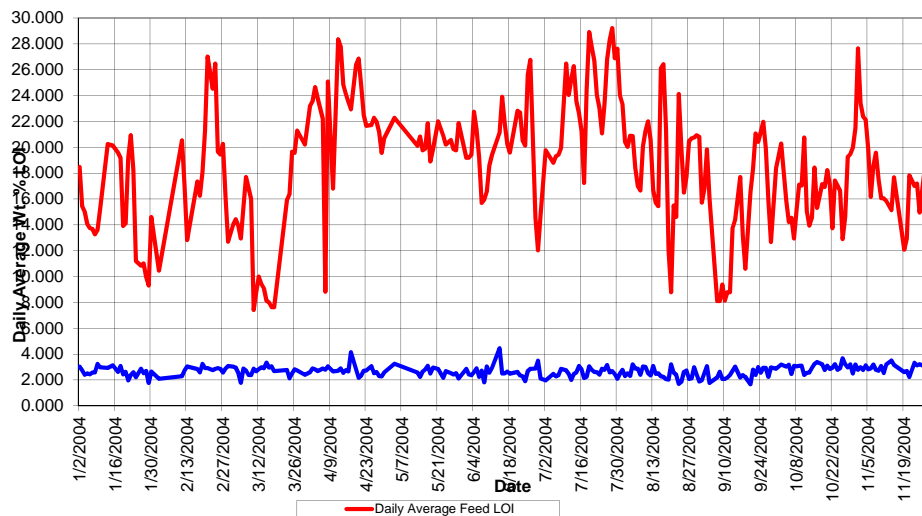
Beneficiation of high LOI fly ash

- ◆ Separation Technologies triboelectrostatic carbon separator
 - ◆ ProAsh® - controlled low LOI fly ash by concrete applications
 - ◆ Simultaneous recovery of concentrated carbon for energy recovery



Quality of Processed Ash for Concrete Applications

**Daily Average Feed ash and Product Ash LOI
ST Jacksonville**

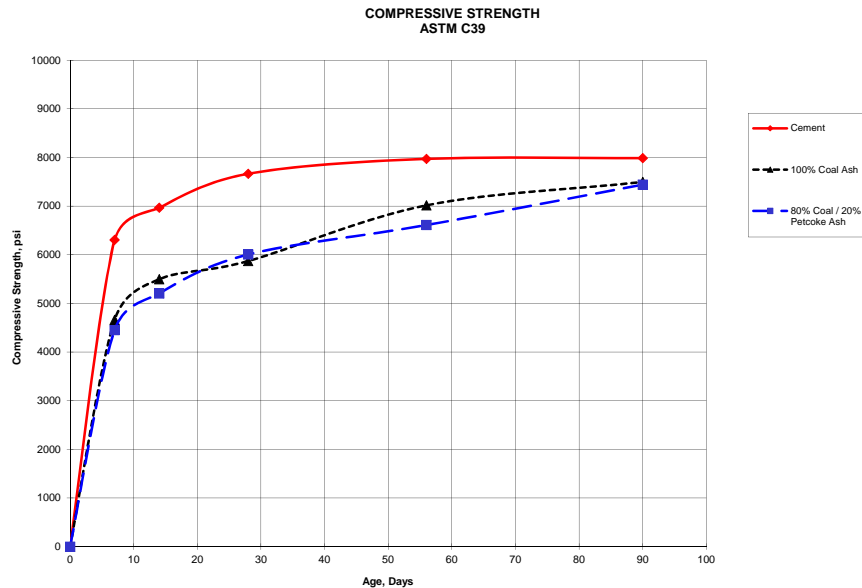




Florida DOT Testing

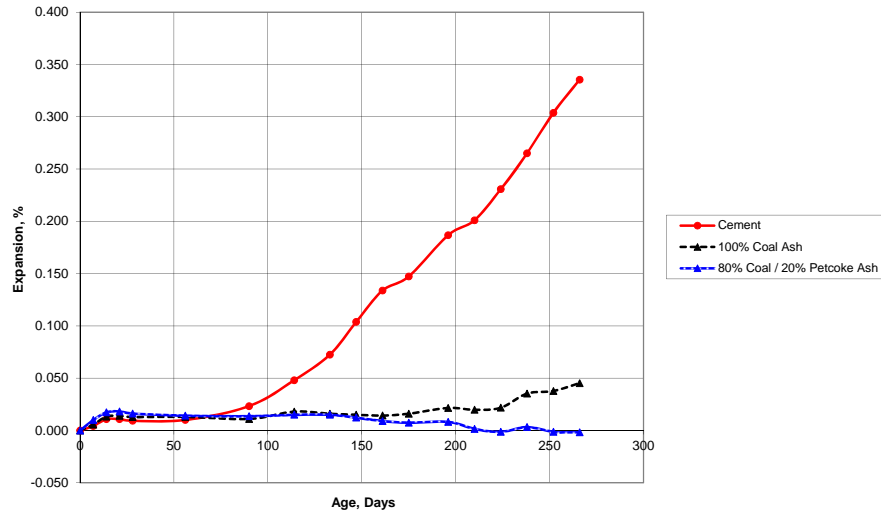
- ◆ 2000 Performance testing of coal/petcoke ash
 - ◆ All ASTM 618 / AASHTO M 295 physical and chemical properties
 - ◆ Strength development to 90 days - ASTM C 39
 - ◆ Sulfate expansion - ASTM C 1012
 - ◆ Drying Shrinkage - ASTM C 157
 - ◆ Corrosion properties - ASTM G 109 & FM 5-522
 - ◆ Chloride permeability - AASHTO T-277
 - ◆ Chloride content - FM 5-516

Compressive Strength



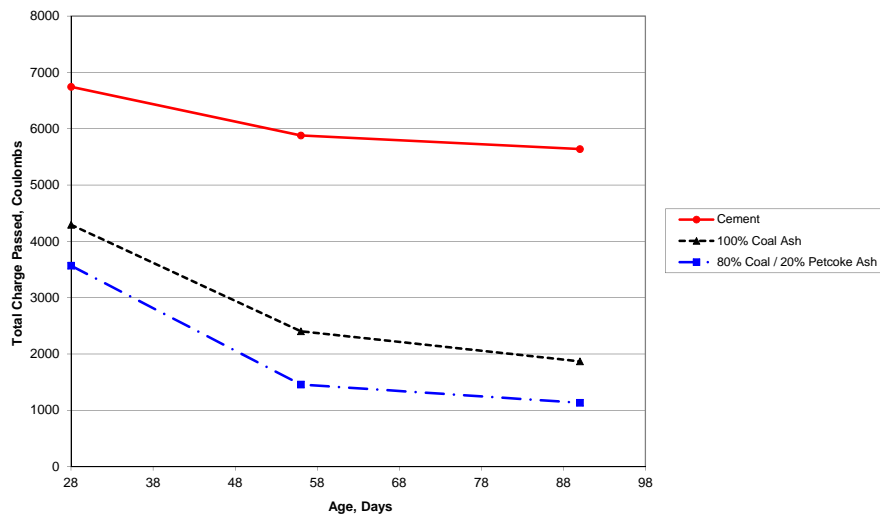
Sulfate Resistance

LENGTH CHANGE OF HYDRAULIC MORTARS EXPOSED TO SULFATE
ASTM C 1012



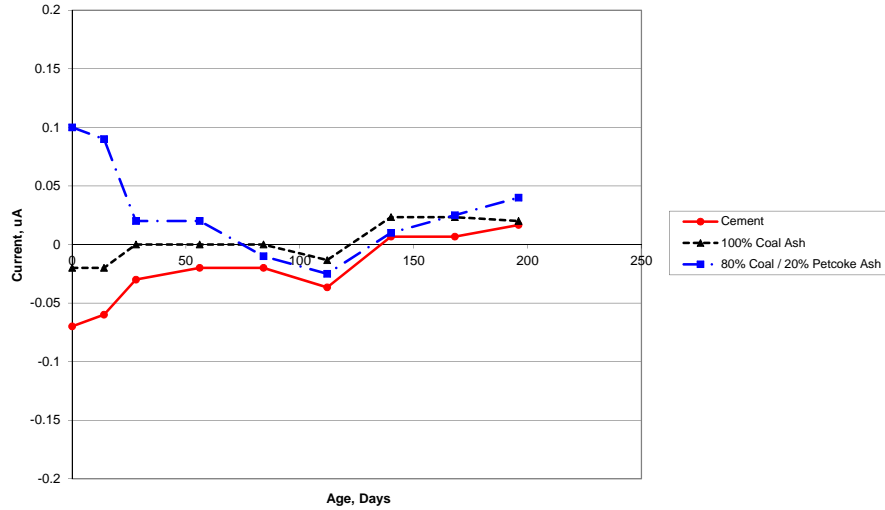
Chloride Permeability

RAPID CHLORIDE PERMEABILITY
ASTM C1202



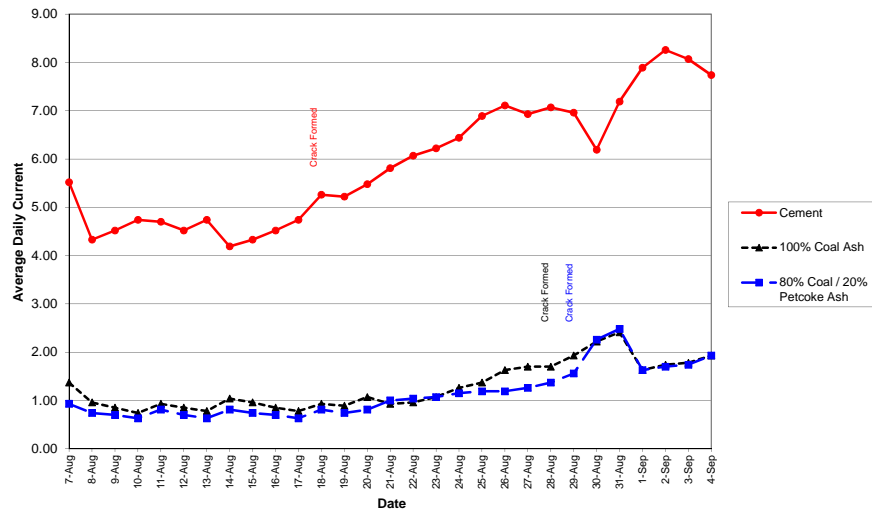
Corrosion of Rebar

EFFECTS OF CHEMICAL ADMIXTURES ON THE CORROSION OF EMBEDDED STEEL
ASTM G-109



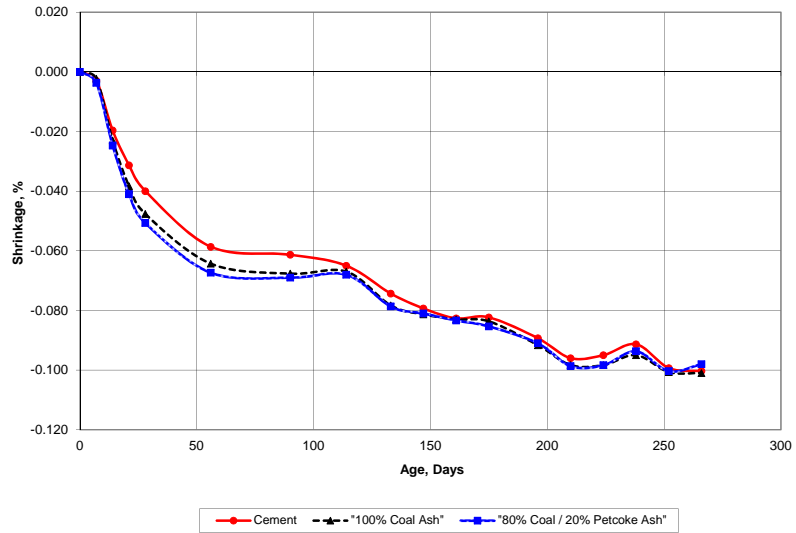
Corrosion of Rebar

CORROSION TESTING OF REINFORCED CONCRETE USING IMPRESSED CURRENT
FM-522



Drying Shrinkage

LENGTH CHANGE OF HARDENED HYDRAULIC CEMENT CONCRETE -
Drying Shrinkage
ASTM C 157

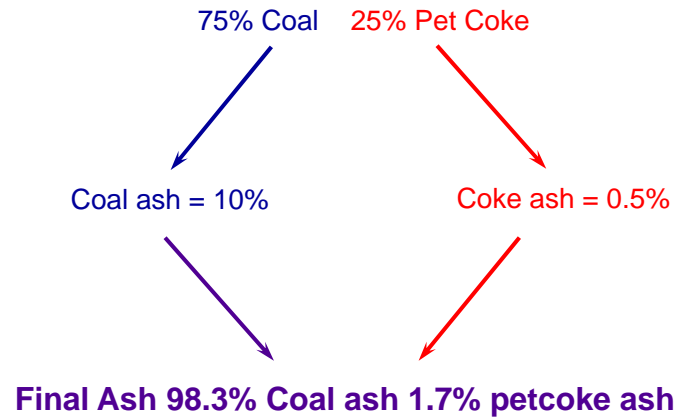


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NB Power Belledune
Station



Fuel at NB Power Belledune Station



Report To Canadian Standards Association

Allan Scott and Michael Thomas

Department of Civil Engineering, University of New Brunswick

- ◆ **Multiple petcoke / LOI levels**
- ◆ **Fly Ash Properties**
 - ◆ CSA A3000 specifications
- ◆ **Fresh Concrete Properties**
 - ◆ AEA Demand
 - ◆ Water Requirement
 - ◆ Set Time

Report To Canadian Standards Association

Allan Scott and Michael Thomas

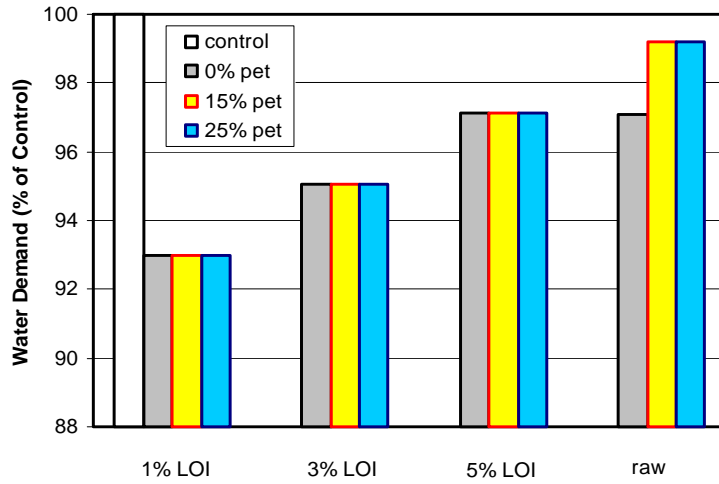
Department of Civil Engineering, University of New Brunswick

- ◆ **Hardened Concrete Properties**
 - ◆ Compressive strength, ASTM C 39
 - ◆ Air-void parameters, ASTM C 457
 - ◆ "Rapid chloride permeability", ASTM C 1202
 - ◆ Deicer salt scaling, ASTM C 672
 - ◆ Freeze-thaw resistance, ASTM C 666
 - ◆ Drying shrinkage, ASTM C 157

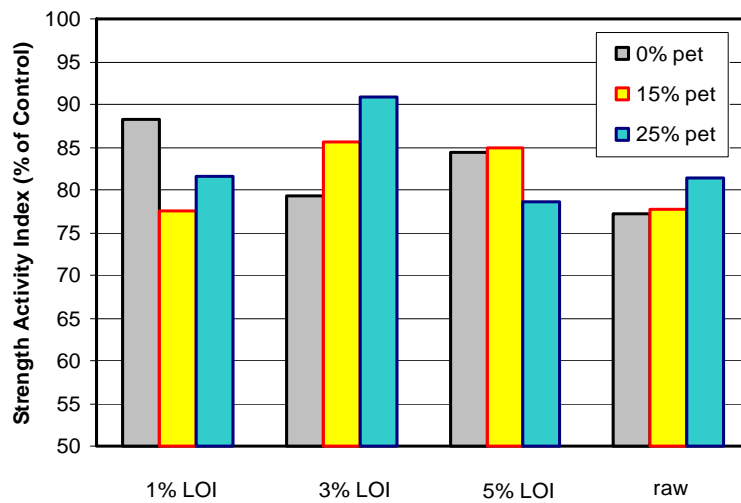
LOI of Fly Ashes from Belledune after Carbon Removal

Target LOI	Pet Coke Content (%)		
	0	15	25
Raw	5.8	7.3	14.1
5%	5.9	4.1	4.6
3%	2.6	2.0	2.9
1%	0.9	0.5	0.7

Water Requirement – ASTM C 109



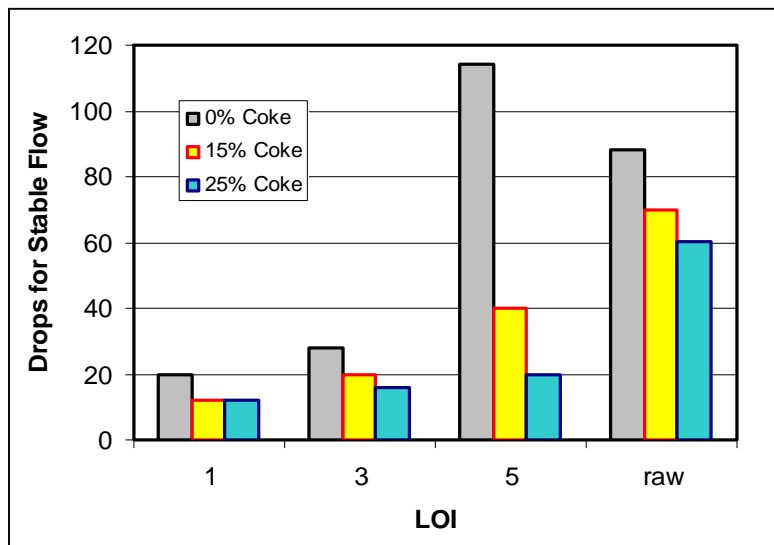
Strength Activity Index (at 28 days)

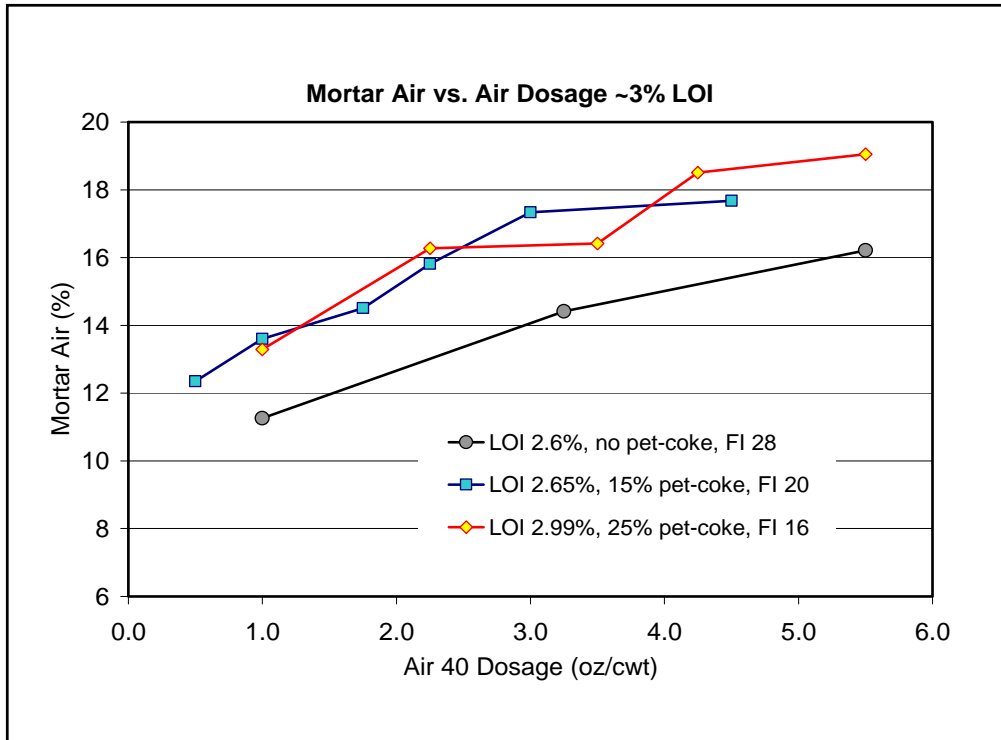


**Setting Time of Pastes (ASTM C 191)
Fly Ashes with 3% LOI**

Sample	Setting Time (mins)	
	Initial	Final
PC Control	153	225
0% Pet Coke	140	255
15% Pet Coke	148	270
25% Pet Coke	152	300

Results of Foam Index Tests





**AEA Requirement for 18% Air in Mortar (ASTM C 185)
Fly Ashes with 3% LOI**

<i>Sample</i>	<i>Vinsol resin/binder ratio</i>
PC control	0.0013
0% pet coke	0.0022
25% pet coke	0.0012

Concrete Mixes

	Control	0% Coke	25% Coke
Cement (kg/m ³)	375	300	300
Fly Ash (kg/m ³)	-	75	75
Water	150	150	150
W/CM	0.4	0.4	0.4
AEA (mL/100 kg)	25	50	50
WRA (mL/100 kg)	200	200	200
HRWA (mL/100 kg)			
Air (%)	6.5	7.0	7.5
Slump (mm)	100	120	130

Concrete Test Results

Test	Control	Fly Ash (3% LOI)	
		0% Coke	25% Coke
<u>Strength (MPa)</u>			
7 days	29.7	24.3	24.0
28 days	35.5	28.2	28.0
90 days	44.2	38.5	37.6
<u>RCPT (Coulombs)</u>			
28 days	4250	3510	3220
90 days	3298	2462	2362
<u>Drying Shrinkage (%)</u>			
28 days	0.032	0.035	0.037
56 days	0.051	0.051	0.053
112 days	0.058	0.057	0.059

Concrete Test Results

Test	Control	Fly Ash (3% LOI)	
		0% Coke	25% Coke
<u>Hardened Air Voids</u>			
Total (%)	6.3	8.4	8.9
Spacing Factor (mm)	0.165	0.088	0.074
<u>Salt Scaling</u>			
Visual Rating	2	4	3
Mass loss (g/m ²)	288	811	725
<u>Durability Factor</u>			
300 Cycles	99.7	99.1	99.7

Conclusions

- ◆ **Petcoke contributes insignificant material to collected fly ash other than carbon**
- ◆ **ST process removes carbon to 3 ± 0.5 % level**
- ◆ **Reduce LOI coal/petcoke ash meets CSA, ASTM, and AASHTO specifications for chemical and physical properties**
- ◆ **Reduce LOI coal/petcoke ash performance equivalent to 100% coal ash in concrete products**
- ◆ ***Florida DOT allows coal/petcoke ash for all work, May 2002***
- ◆ ***Canadian Standards Association (CSA) allows fly ash from coal/petcoke blends, May 2004***

**CSA – A3000 Cementitious Materials Compendium
Update No. 2 July 2004**

Fly ash — the finely divided residue that results from the combustion of pulverized coal or a combination of pulverized coal blended with up to 30% by mass of petroleum coke and that is carried from the combustion chamber of a furnace by exhaust gases.

Notes:

2) The co-combustion of coal and petroleum coke may change the relationship between loss-on-ignition and air-entraining admixture requirements.

Petroleum coke — a solid product of petrochemical refining of heavy residual fuel oils

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