Reducing the CO_2 of Concrete Mixtures for Bridges.

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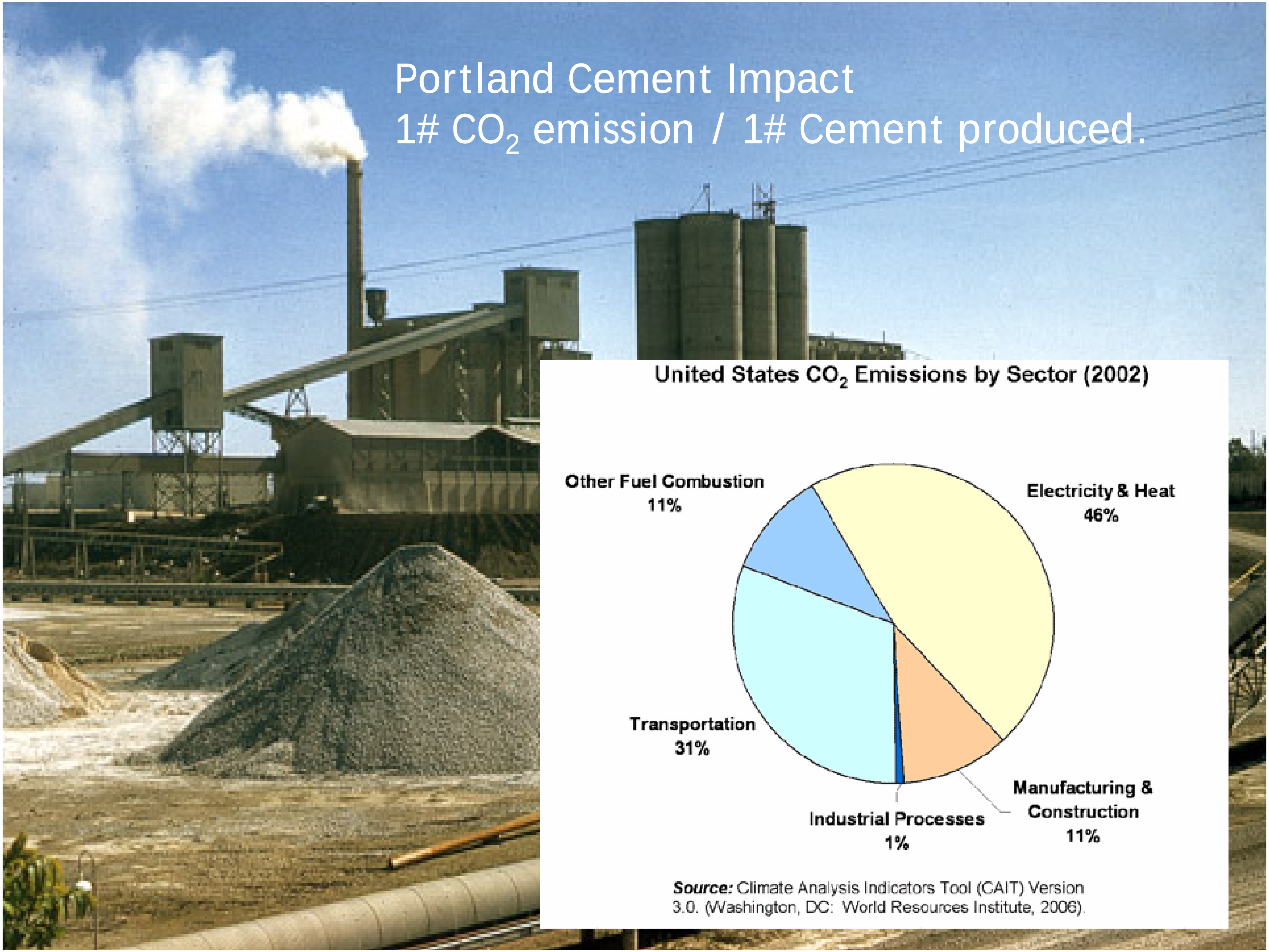
Sustainable design; to meet the needs of the present without compromising the ability of future generations to meet their needs.


~125AD
M·AGRIPPA·L·F·COS·TERTIVM·FECIT

Portland Cement Impact

1# CO_2 emission / 1# Cement produced.



Concrete: Part of a sustainable future.

- Besides water, the most commonly used material (by vol.) on earth.
- Service-life & life-cycle advantage over other construction materials; reduced maintenance.
- Cement production is responsible for 1-3% of US greenhouse gases emissions.
- Concrete reabsorbs most of the CO_2 emitted by calcination during cement production over the structures life, or shortly after demolition.
- 20-70% energy from alternative fuels – consumer waste & by-products.
- 33% less emissions since ’75, and Industry goal to reduce another 10% by ’20.

(PCA)

Concrete: Part of a sustainable future.

- Raise reflectivity of pavements 15% offsets 4nt CO_2 emissions per 1000 sqft.

  - 47% of global GHG emissions could be offset with light-colored pavements.

(CA Energy Comm)

EPA Part 247- Comprehensive Procurement Guidelines for Products Containing Recovered Materials – 2004.

COMPARISON OF CHEMICAL AND PHYSICAL CHARACTERISTICS — PORTLAND CEMENT, FLY ASH, SLAG CEMENT, AND SILICA FUME

Note that these are approximate values. Values for a specific material may vary from what is shown. (Note 1)

PROPERTY	PORTLAND CEMENT	CLASS F FLY ASH	CLASS C FLY ASH	SLAG CEMENT	SILICA FUME
SiO_2 content, %	21	52	35	35	85 to 97
$Al2O_3$ content , %	5	23	18	12	
Fe_2O_3 content ,%	3	11	6	1	
CaO content ,%	62	5	21	40	< 1
Fineness as surface area, m^2/kg *(Note 2)*	370	420	420	400	15,000 to 30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General use in concrete	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

Note 1. Information from SFA and Kosmatka, Kerkoff, and Panarese (2002).

Note 2. Surface area measurements for silica fume by nitrogen adsorption method. Others by air permeability method (Blaine).

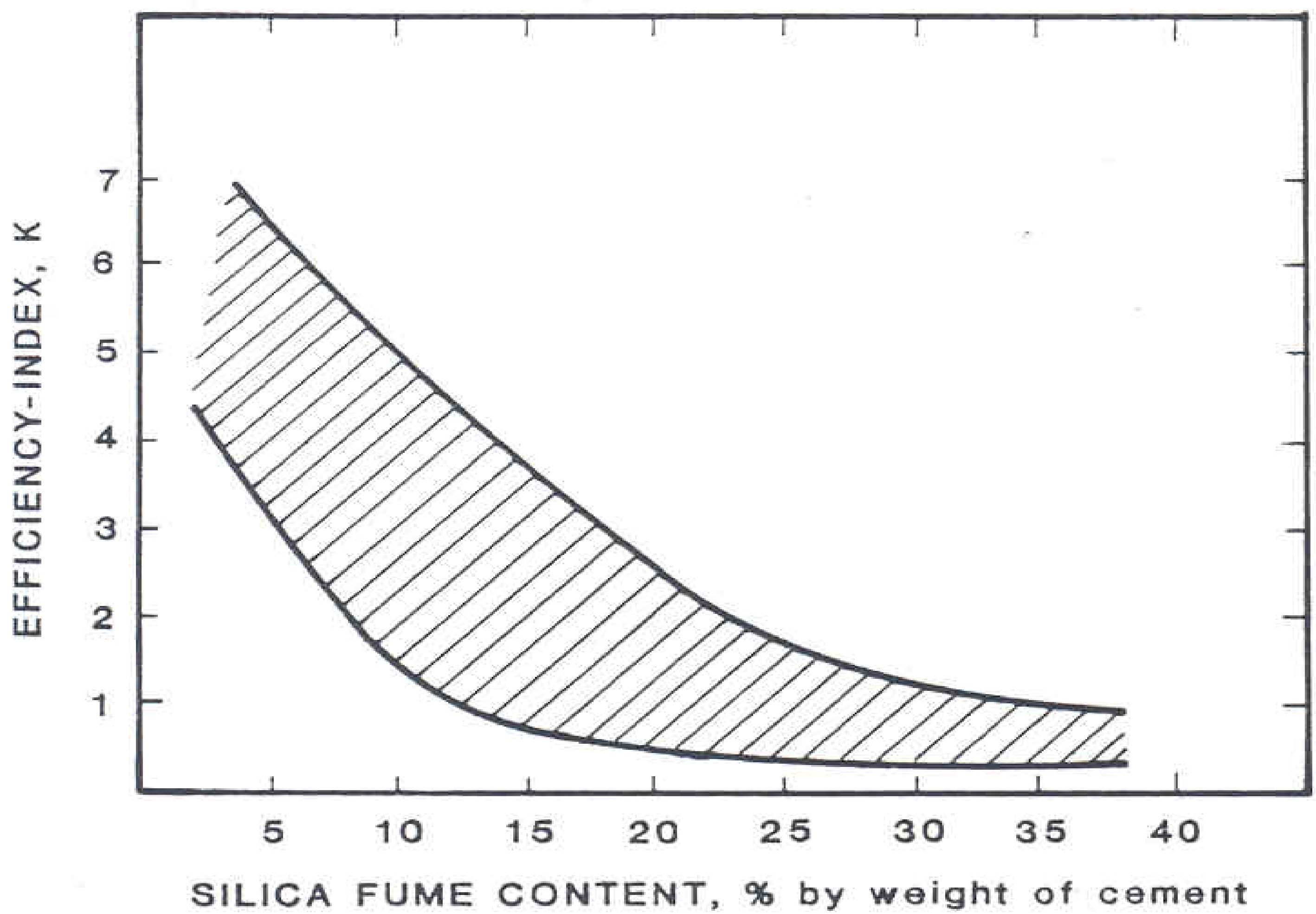


FIGURE 5. A generalized relation between efficiency index and silica fume content of concrete.

Fundamentally HPC is green Technology

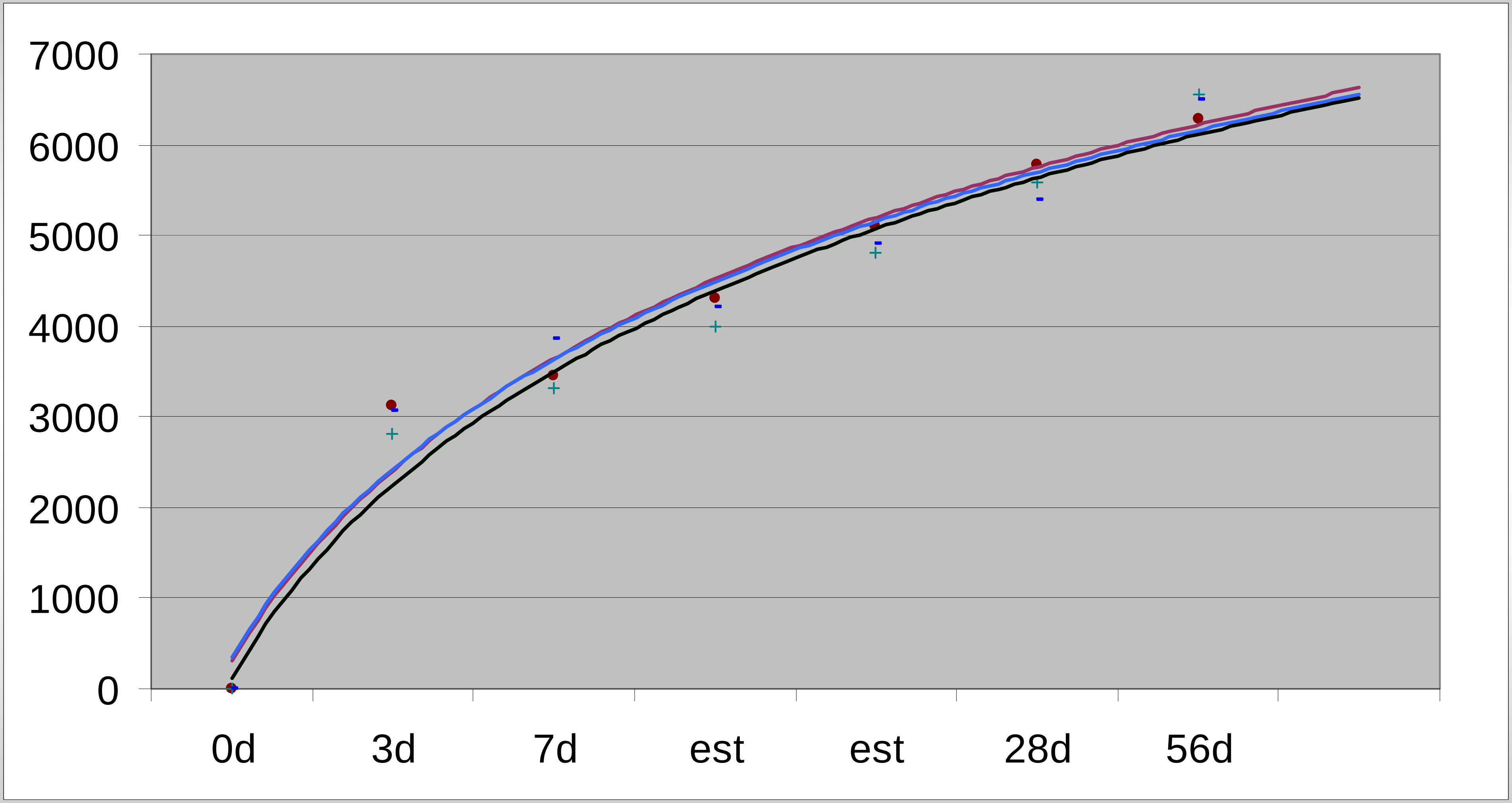
- Implies using the least amount of cement possible!
- Judicious use of EPA - SCMs.
  - Particle packing - reduced permeability.
  - ASR control.
  - Less water - less shrinkage.
  - Reduced heat of hydration.
  - Lower strength - reduced cracking, or
  - Optimized for early strength.
- NYC Building Code ('08) limits cement content; Max. 400pcy.

Sustainable

HPC Mixtures - low shrinkage & permeability – I-99 Bridge Decks.

% Cement	70	65	70
PCY			
Cement	394.8	366.6	427.7
Slag			
Fly Ash	152.3	169.2	165
Silica Fume	16.92	28.2	18.33
CA, #58	1858	1858	1858
FA	1133.5	1124.8	1045.6
Water	242.53	242.52	262.74
AEA, oz/cwt	0.65	0.7	0.65
MRWR	7	7	7
HRWR	8	9	6
Slump	6	6	6.5
Air	5.75	5.25	6
w/cm	0.43	0.43	0.43

Strength results



90-2.01C Required Use Of Supplementary Cementitious Materials

General

The amount of portland cement and SCM used in portland cement concrete shall conform to the minimum cementitious material content provisions in Section 90-1.01, "Description," or Section 90-4.05, "Optional Use of Chemical Admixtures," and these specifications.

The SCM content in portland cement concrete shall conform to one of the following:

A. Any combination of portland cement and at least one SCM, satisfying Equations (1) and (2):

Equation (1)

$$\frac{(25 \times UF) + (12 \times FA) + (10 \times FB) + (6 \times SL)}{MC} \geq X$$

Where:

UF = Silica fume, metakaolin, or UFFA, including the amount in blended cement, pounds per cubic yard.

FA = Fly ash or natural pozzolan conforming to the requirements in AASHTO Designation: M 295, Class F or N with a CaO content up to 10 percent, including the amount in blended cement, pounds per cubic yard.

FB = Fly ash or natural pozzolan conforming to the requirements in AASHTO Designation: M 295, Class F or N with a CaO content up to 15 percent, including the amount in blended cement, pounds per cubic yard.

SL = GGBFS, including the amount in blended cement, pounds per cubic yard.

MC = Minimum amount of cementitious material specified, pounds per cubic yard.

X = 1.8 for innocuous aggregate, 3.0 for all other aggregate.

CALTRANS – 2009

Section 90

Equation (2)

MC – MSCM - PC	≥ 0

Where:

MC = Minimum amount of cementitious material specified, pounds per cubic yard.
MSCM = The minimum sum of SCMs that satisfies Equation (1) above, pounds per cubic yard.
PC = The amount of portland cement, including the amount in blended cement, pounds per cubic yard.

B. 15 percent of Class F fly ash with at least 48 ounces of $LiNO_3$ solution added per 100 pounds of portland cement. CaO content of the fly ash shall not exceed 15 percent.

CALTRANS Mixture - Precast SCC

	Ref. pcy	CALTRANS pcy	CO_2 effect
Cem.III	611	535	-76 lbs
Fly ash	76	120	+0.44 lbs
SF		20	+0.32 lbs
CA	1530	1530	
FA	1470	1470	
HRWA	53oz	53oz	
Set NC,	110oz	110oz	
Rapid1,	110oz	80oz	
Water	282	282	
Flow, in.	23	23	
1d, psi	4000*	3600	
7d	5000	7240	
90d	7800	10260	


Sunshine Bridge
WB on I-40
45 miles E. of Flagstaff, AZ
Elevation 5,185
Deck replacement

ADOT SCM-HPC mix

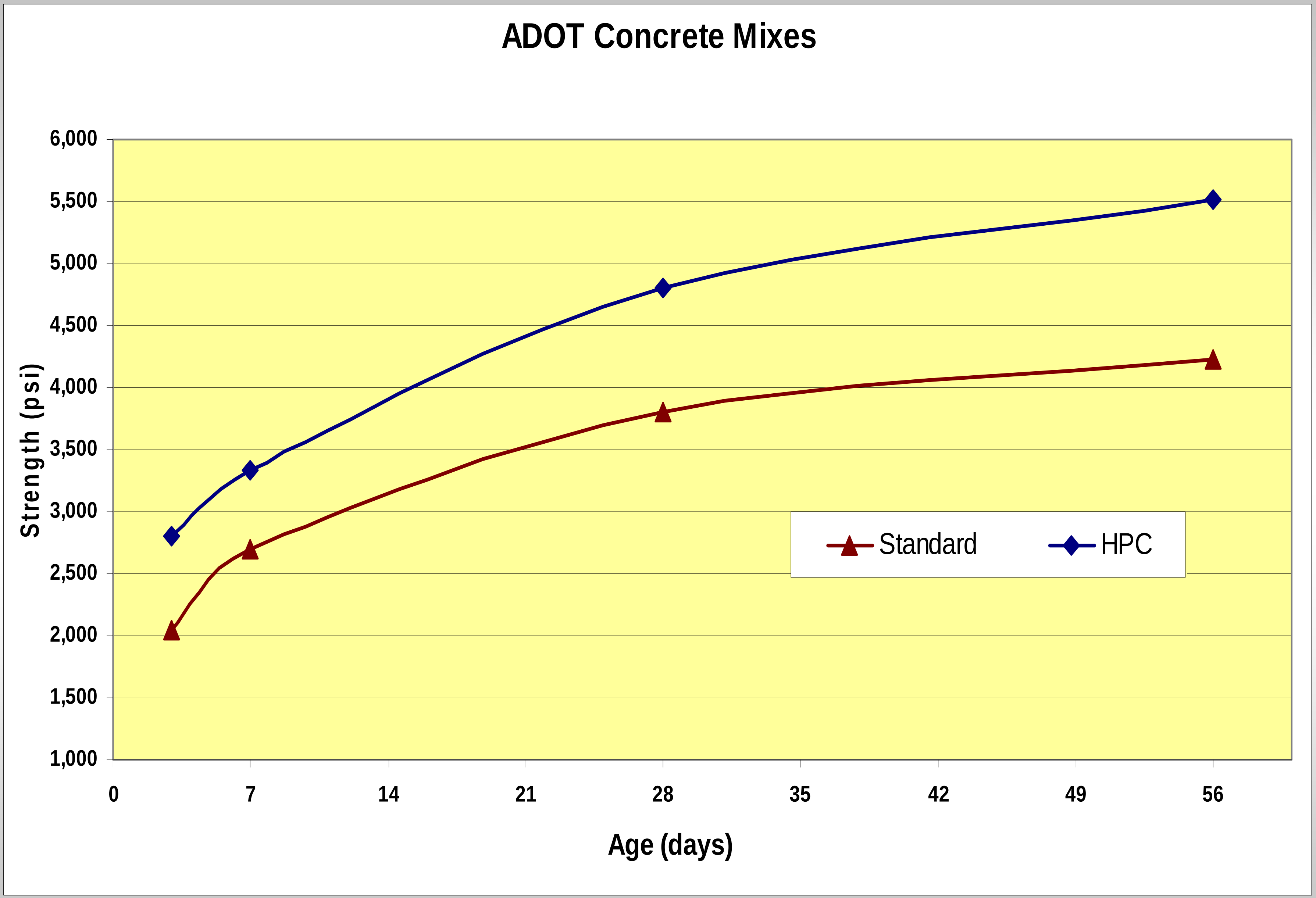
compared to

AODT Class S standard bridge deck mix

Materials		Standard	HPC
Cement content, (lb/yd^3)		530	450
Fly Ash (lb/yd^3)		110	110
Silica Fume, (lb/yd^3)		0	23
Fine Agg. (lb/yd^3)		1244	1181
Coarse Agg. (lb/yd^3)		1592	1765
Water, (lb/yd^3)		276	250
Water/cementitious ratio		0.43	0.43
Slump, (inch)		4	4
Air content, %		5.30%	5.60%
Paste content, %		30%	27%
Permeability 56 days (Coulomb)		2610	768
Compressive Strength (psi)	3 days	2040	2810
	7 days	2700	3340
	28 days	3810	4810
	56 days	4230	5510

ADOT SCM Application

- ***80 pounds less cement***
- ***3 gallons less water***
- ***Reduced paste from 30 to 27 %***
- ***Reduced shrinkage***
- ***Increased compressive strength***
- ***Reduced permeability (3 times)***


ADOT Concrete Mixes
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
Strength (psi)
0
7
14
21
28
35
42
49
56
Age (days)
Standard
HPC

ADOT SCM Application

Age	Modulus of Elasticity (psi), ASTM C-470					
	Average	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
3-day	3,283,333		3,400,000	3,200,000	3,250,000	
7-day	3,500,000		3,550,000	3,450,000	3,500,000	
28-day	3,980,000	4,100,000	4,150,000	3,900,000	4,000,000	3,750,000

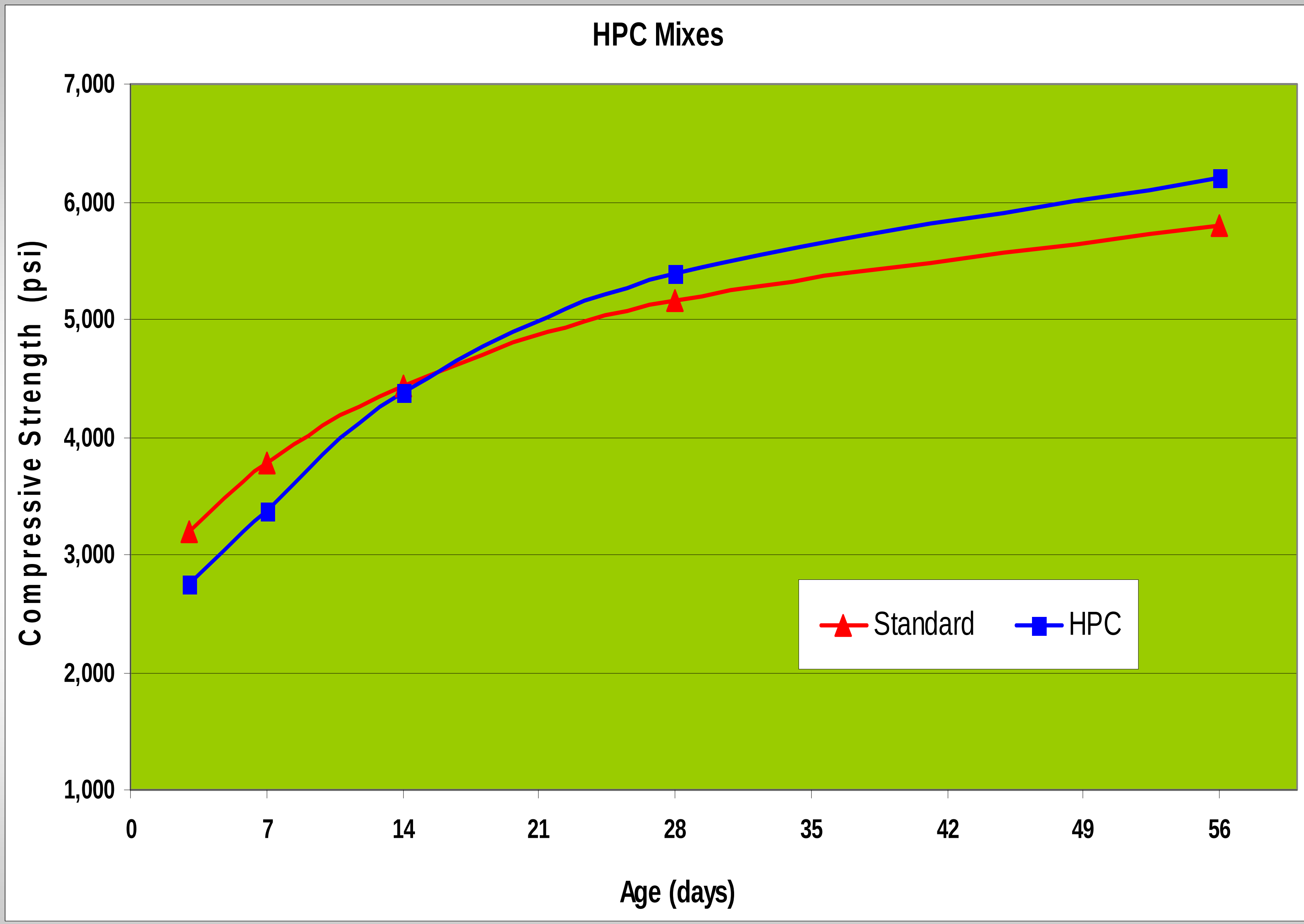
Core	Rapid Chloride Permeability (Coulomb), ASTM C-1202					
	At 56 days	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
A	984	983	1042	1029	1123	936
B		953	973	944	989	871
Average		968	1008	987	1056	904

Chicago DOT HPC mix (I-90)

compared to

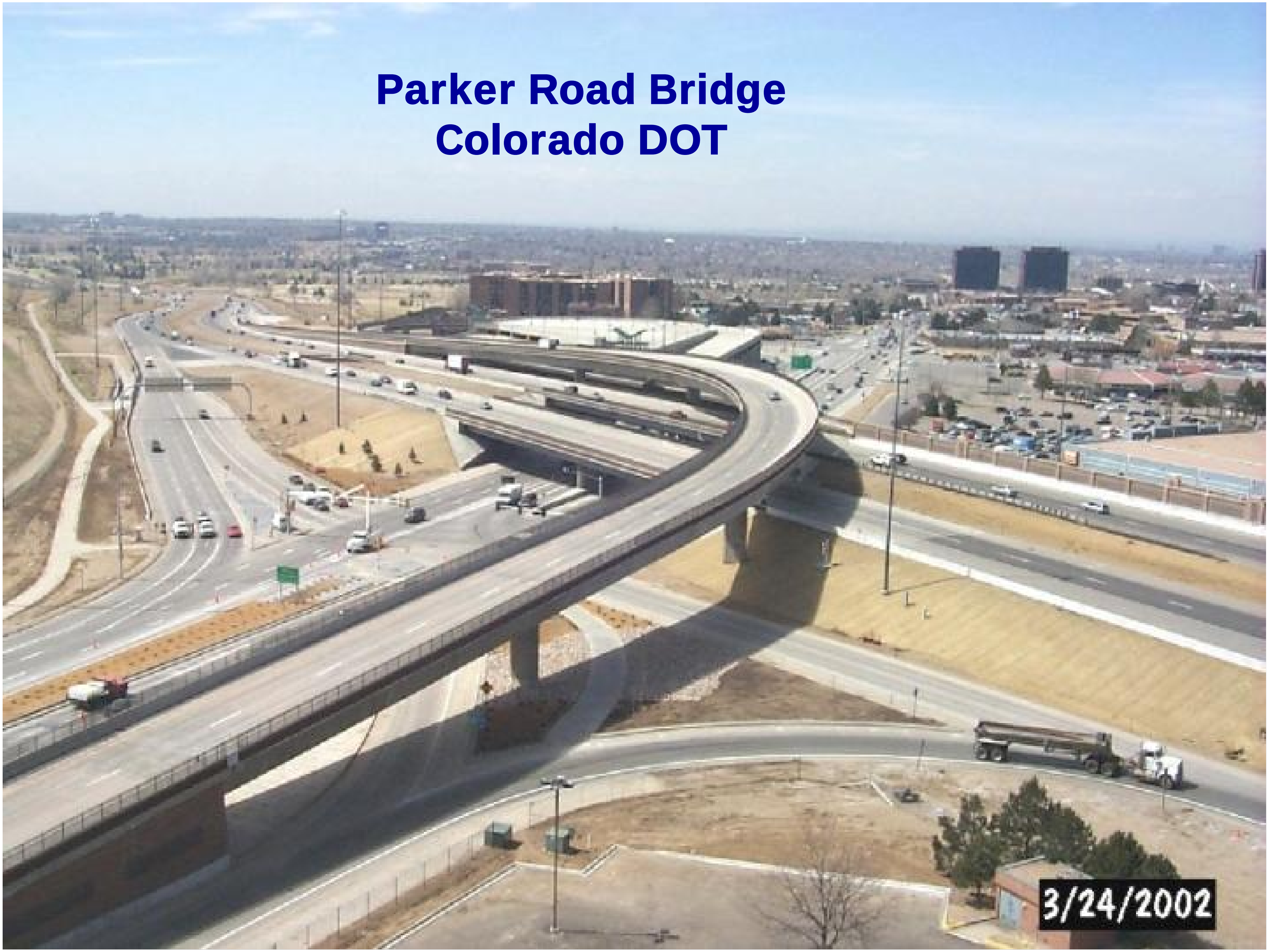
ILDOT Class AAA standard bridge deck mix

Material		HPC		ILDOT Mix	
		Mass	Volume	Mass	Volume
Cement, pcy		470	2.39	665	3.39
Fly Ash, pcy		100	0.64	117	0.75
Silica Fume, pcy		40	0.29	-	-
Water, gal		29.8	3.97	36.8	4.91
Total Volume, ft3			7.29		9.05
Water/Cementitious Ratio			0.407		0.392
Crushed Gravel, pcy		1770		1680	
Natural Sand, pcy		1190		993	
Aggregate Volume, ft3			17.96		16.2
AEA, oz/cwt (6.5%)		0.8	1.75	0.9	1.75
Permeability, coulomb		1200		2850	
Compressive Strength, psi	3 days	2760		3200	
	7 days	3370		3770	
	14 days	4380		4440	
	28 days	5390		5160	
	56 days	6210		5790	
28:7 day ratio, min. 1:40		1.6		1.37	



HPC Mixes
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Compressive Strength (psi)
0
7
14
21
28
35
42
49
56
Age (days)
Standard
HPC

Parker Road Bridge
Colorado DOT



CDOT SCM-HPC mixtures.

MIX Materials/Properties		Range
Cement content, (lb/yd^3)		465 to 485
Fly ash (lb/yd^3)		93 to 120
Silica fume, (lb/yd^3)		18 to 20
Water/cementitious ratio		0.37 to 0.41
Sand, (lb/yd^3)		1231 to 1398
Gravel, (lb/yd^3)		1595 to 1780
HRWR (oz/100 lb cement)		5 to 12
AEA, (oz/100 lb cement)		0.50 to 1.5
Retarder, (oz/100 lb cement)		2 to 3
Slump, (inch)		4 to 6
Air content, %		5.5 to 8.5%
Permeability at 28 days (Coulomb)		2700 to 2900
Permeability at 56 days (Coulomb)		1400 to 1600
First cracking (days)		14 to18
Compressive Strength (psi)	3 days	2500-3500
	7 days	3500-4300
	28 days	4600 to 5600
	56 days	5400 to 6600

OR DOT - SCM Application.

1998, Brush Creek Bridge
(all members) - 30% Fly ash,
and 4% Silica fume.

October 2003,
1st designated
Class of HPC.

Conclusion

- The sustainability of concrete bridge structures can be improved incrementally by optimizing the SCMs used.
  - Lower Concrete initial CO_2 impact.
  - SCMs extend service-life and improved LCC of bridges.
- HPC and green technology are parallel.
- Industry's challenge: Break the paradigm of 100-yrs of over-using Portland cement.
  - 'We've never made concrete like this before'.
  - New blended-SCM products coming into the mkt.
- Recognition of Concrete's total environmental impact.


Thank you.