ACI Spring Convention
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Off the Chart Concrete Mixture Proportioning

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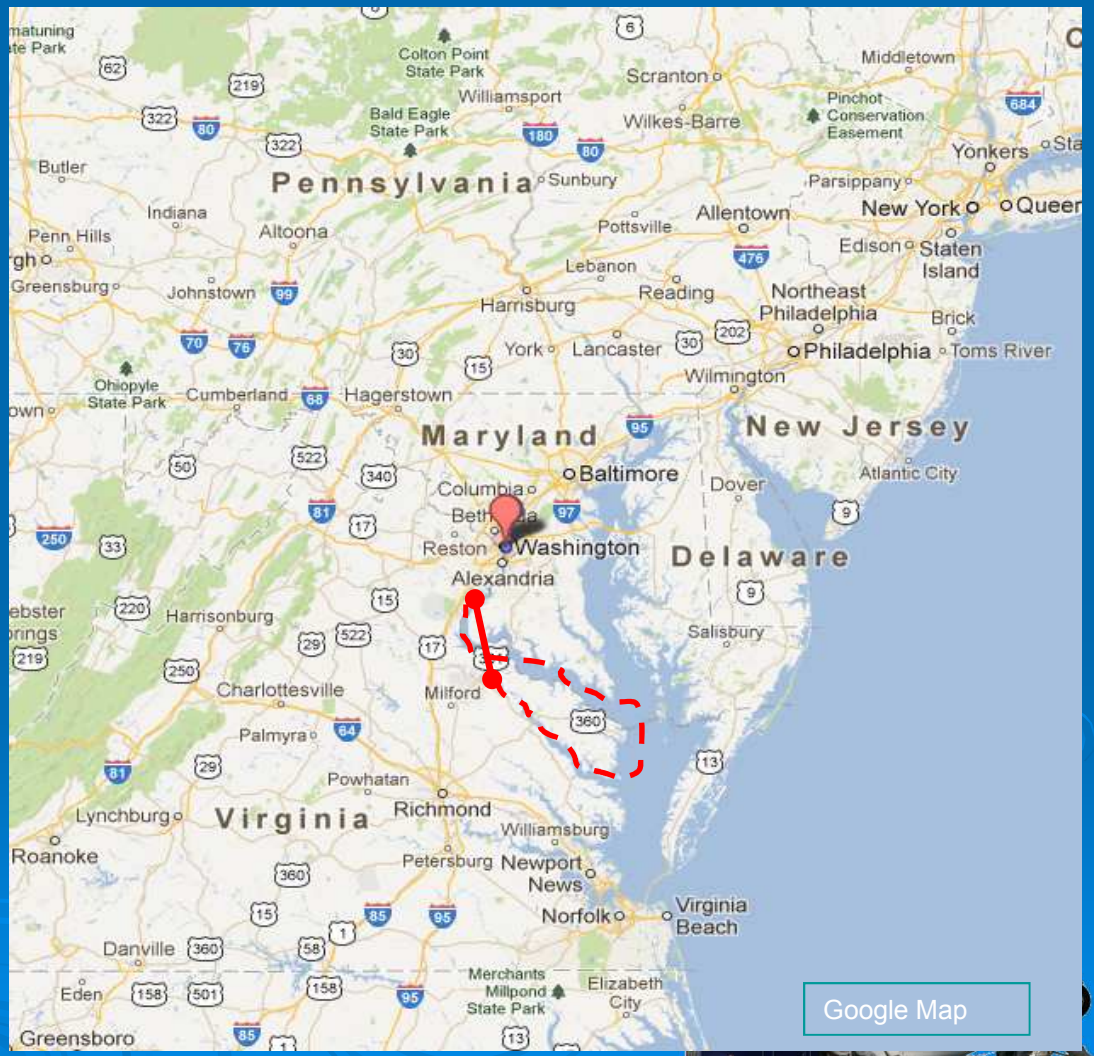
Overview

- Mix proportioning using non-traditional fine aggregates
  - Fineness Modulus (FM>3.0)
  - Minus #200 sieve (<75 µm) material > 7%
- They are from finer fractions of crushed stones, a.k.a “manufactured sand”.

Why non traditional fine aggregates?

- Looming natural sand shortage due to:
  - Urban sprawl and NIMBY
  - Permitting issue
  - Transportation cost



Barriers to Manufactured sand:

- Concrete finishers hate it
  - difficult to “close” with a trowel.
  - like rubbing on stone with a trowel
- Pump men hate it
  - High pump pressure – more wear/tear
- Ready mixed guy (me) hates it
  - My customers hate it
  - Higher water demand – need more cementitious materials to meet specified water-cementitious ratio (w/cm)

Manufactured sands are not created equal

1. High Fineness Modulus (FM) >3.0
2. High fines (< #200 sieve : 12 to 20%)
3. Regular fines (<#200 sieve: 3 to 7%)
4. Pre-Blended with natural sand
5. Rounded and reshaped

Mix proportioning technique: sand with high FM

Manufactured sand with high FM

Sieve No.	Pocomoke Natural sand	Graham Manf sand	Hanover Manf sand
0.375	100.0	100.0	100.0
No.4	97.0	88.2	99.9
No.8	91.5	59.0	90.8
No.16	81.7	39.5	60.5
No.30	58.0	25.7	38.1
No.50	19.9	15.1	18.4
No.100	2.3	6.9	8.1
No.200	0.2	2.8	3.5
FM	2.50	3.66	2.84

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ROSSLYN COMMONS

Arlington, Virginia

Market: Washington, D.C.

Type: Multifamily Residential

Role: Development Partner

Status: Under construction

Mid-rise apartment community being developed in the heart of Rosslyn, one of Arlington's "urban villages," approximately half a mile from the Potomac River.

Size

- 474 rental apartments
- 12,900 square feet of retail space

www.macfarlanepartners.com/projects/rosslyn-commons

Coarse Aggregate Volume Recommended by ACI 211

Table 6.3.6 – Volume of coarse aggregate per unit of volume of concrete

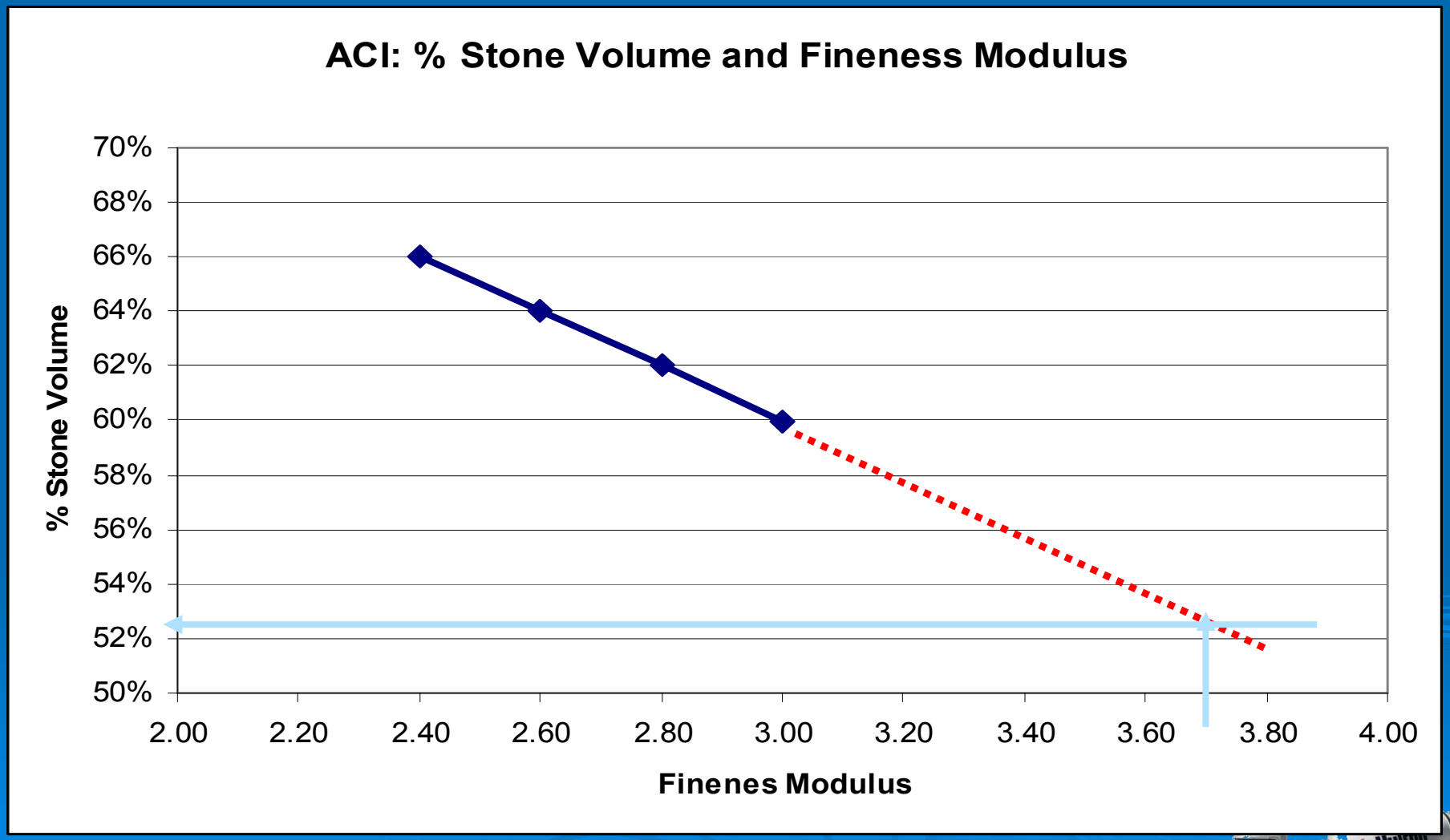
Nominal maximum size of aggregate, in.	Volume of oven-dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli of fine aggregate†			
	2.40	2.60	2.80	3.00
3/8	0.50	0.48	0.46	0.44
1/2	0.59	0.57	0.55	0.53
3/4	0.66	0.64	0.62	0.60
1	0.71	0.69	0.67	0.65
1 1/2	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.80	0.78	0.76
6	0.87	0.85	0.83	0.81

*Volumes are based on aggregates in oven-dry-rodded condition as described in ASTM C 29.

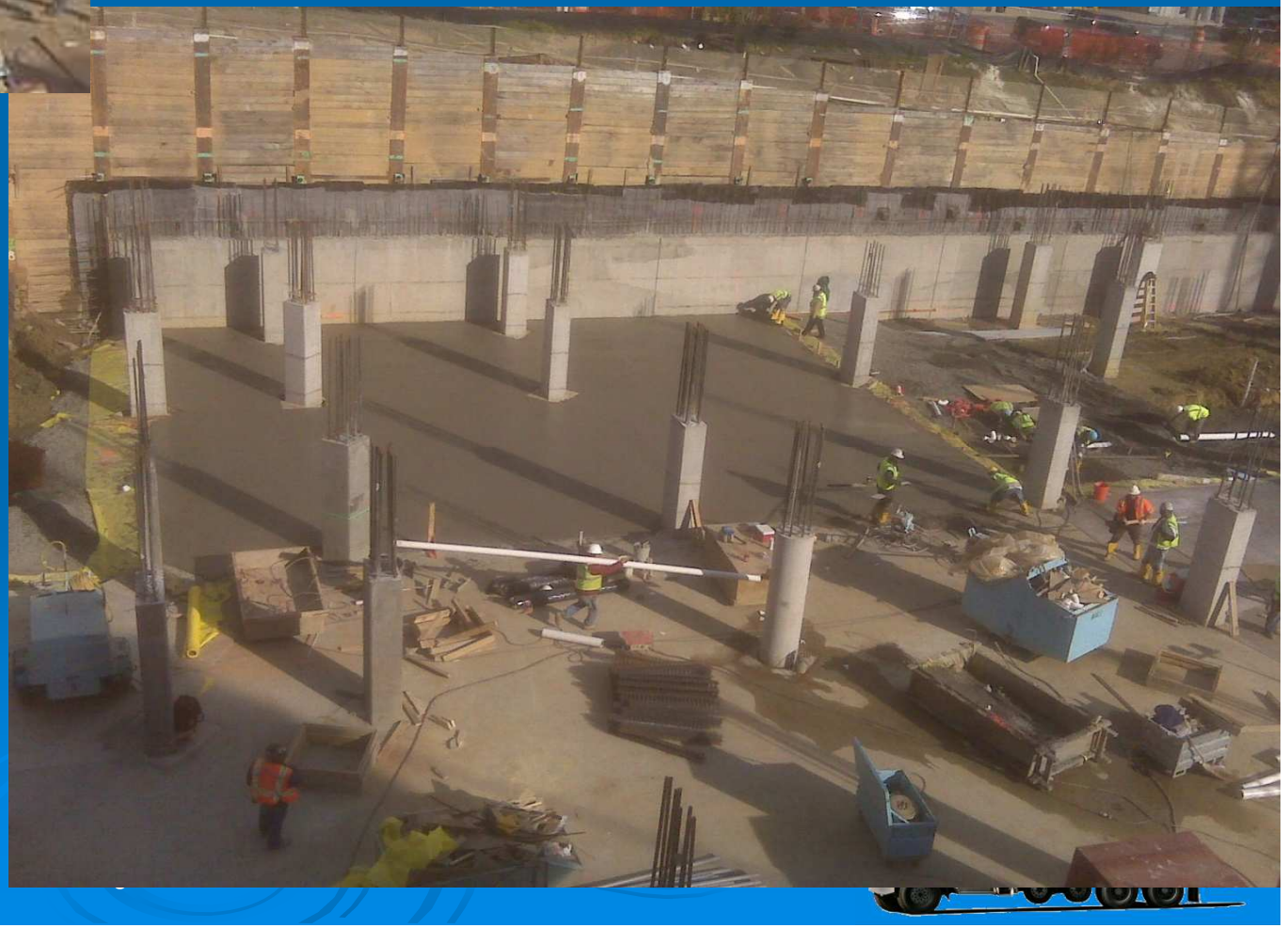
These volumes are selected from empirical relationships to produce concrete with a degree of workability suitable for usual reinforced construction. For less workable concrete, such as required for concrete pavement construction, they may be increased about 10 percent. For more workable concrete see Section 6.3.6.1.

†See ASTM C 1.36 for calculation of fineness modulus.

ACI 211 proportioning chart



100% manufactured sand, FM = 3.66



Placed Oct 26, 2011

Pictures courtesy of Swope Associates

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Use Sand with FM=3.7 with caution!

- The aforementioned project has:
  - An onsite batch plant
  - One concrete finishing crew
  - Committed concrete contractor
  - No pumping – all bucketed
  - Admixtures: superlasticizer, air entrainment

High FM Manufactured sand Blend with Natural Sand

	Manf sand	Natural sand	Combined Fine Agg (by weight)							ASTM C33 VDOT
			Manf sand	*90%*	*80%*	*70%*	*60%*	*50%*	*40%*	*30%*	
			Natural sand	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	
3/8"	100.0	100%		100%	100%	100%	100%	100%	100%	100%	100
#4	97.7	96%		98%	97%	97%	97%	97%	97%	97%	95-100
#8	63.8	87%		66%	68%	71%	73%	75%	78%	80%	80-100
#16	33.9	76%		38%	42%	47%	51%	55%	59%	63%	50-85
#30	19.5	56%		23%	27%	30%	34%	38%	41%	45%	25-60
#50	10.2	25%		12%	13%	15%	16%	18%	19%	21%	5-30
#100	4.4	4%		4%	4%	4%	4%	4%	4%	4%	0-10
#200	2.2	1.8%		2%	2%	2%	2%	2%	2%	2%	0-5
FM	3.71	2.56		3.59	3.48	3.36	3.25	3.13	3.02	2.90	
S.G.	2.93	2.60		2.90	2.86	2.83	2.80	2.77	2.73	2.70	
abs	0.85	0.75		0.84	0.83	0.82	0.81	0.80	0.79	0.78	

Tysons Corner Center

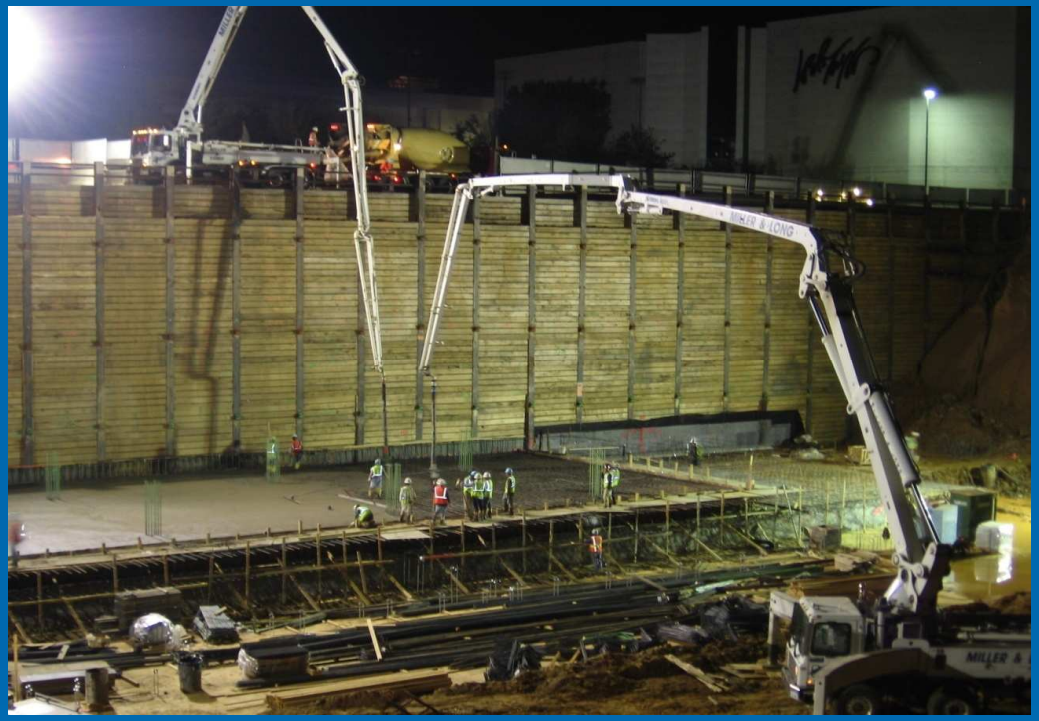
I-495 Express Lanes

Tysons Corner Center

http://www.washingtonpost.com/business/capitalbusiness/macerich-starting-mixed-use-tysons-corner-project-in-early-2012/2011/06/22/AGz5YXjH_story.html

- high-end office building, a 400-unit apartment tower and a four-star hotel

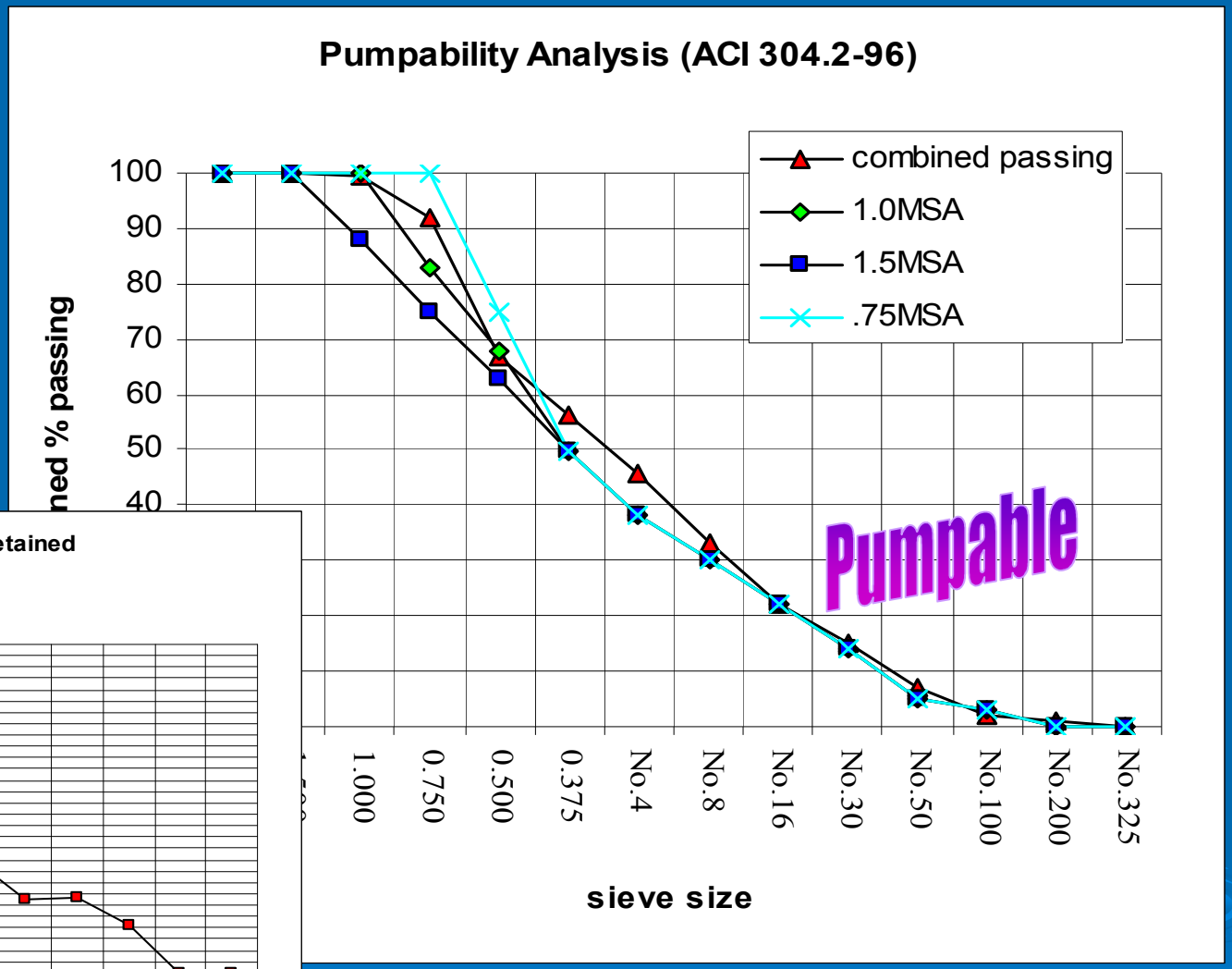
Tysons Corner Center

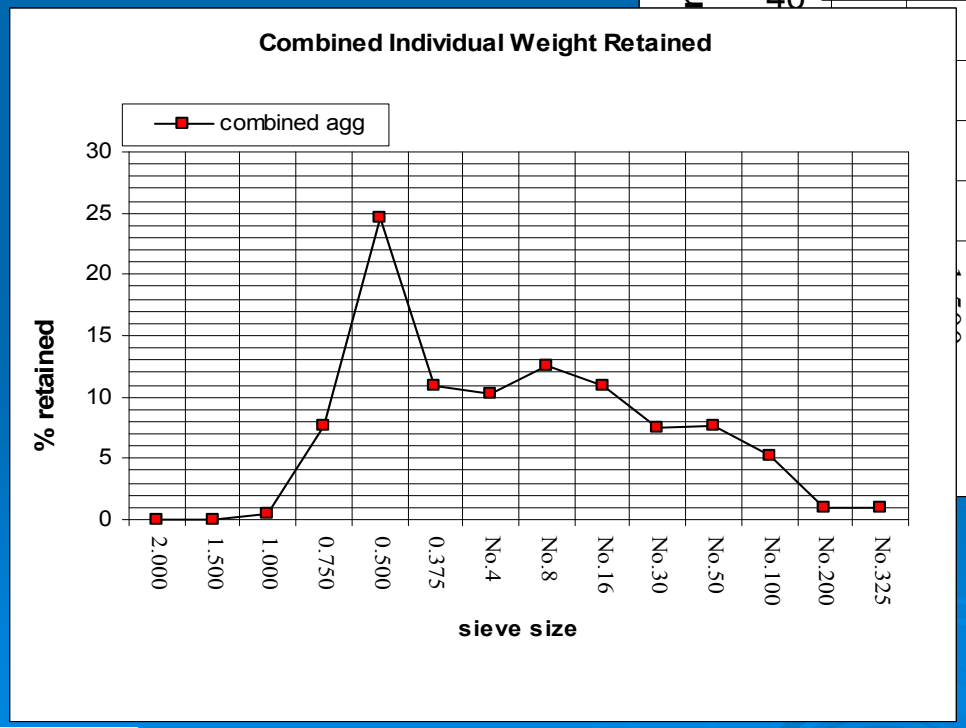


- 60% manf sand, 40% natural sand
- 38,000cy in mat foundation, 3-8ft thick

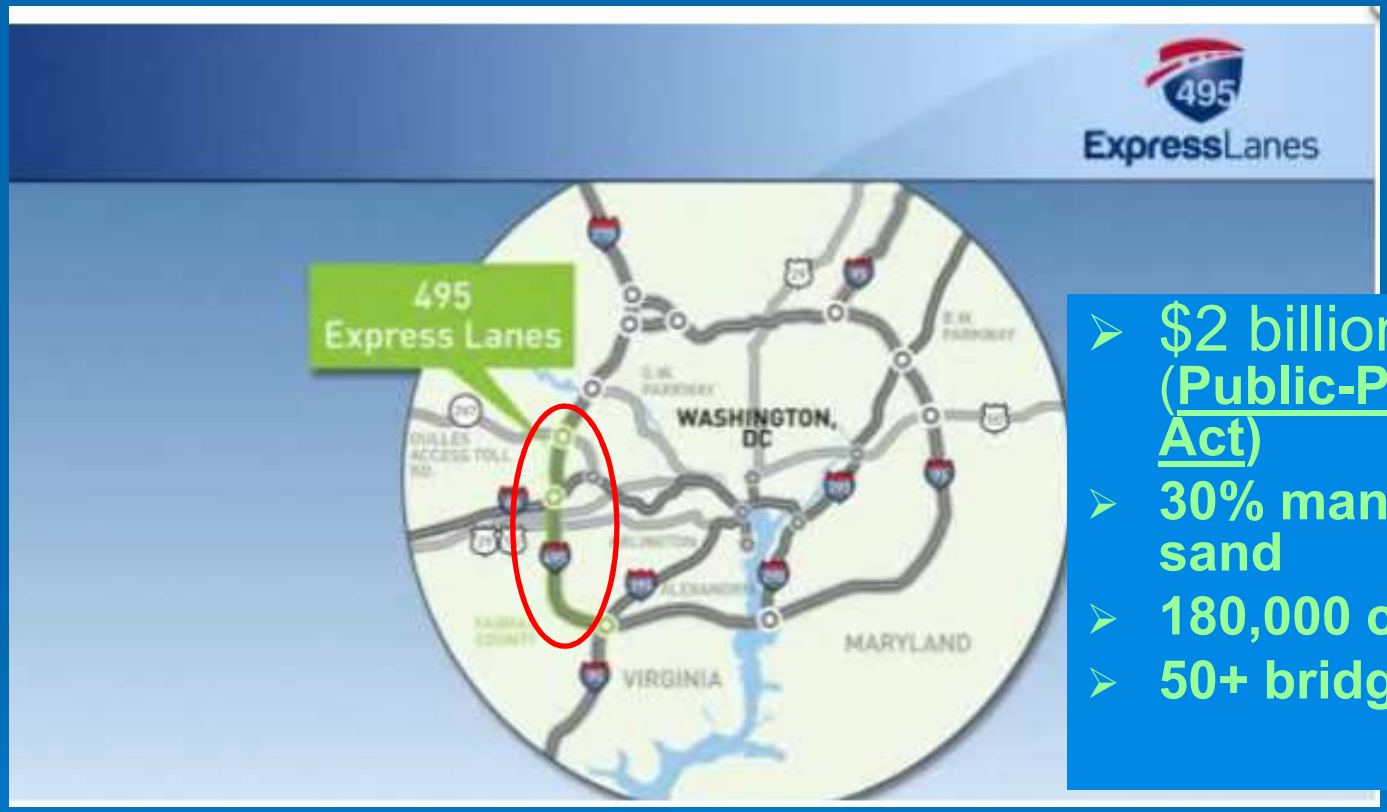
Placed September 14-15, 2012

Tysons Corner Center





I-495 Express Lanes (variable tolls)



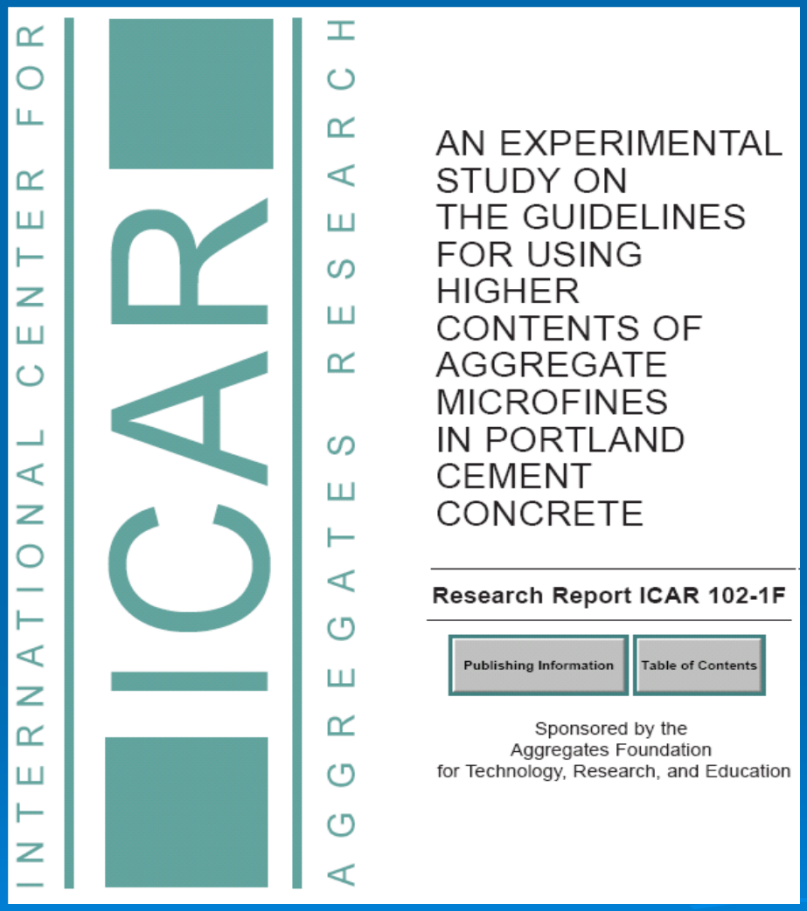
- $2 billion PPTA project (**Public-Private Transportation Act**)
- **30% manf sand + 70% natural sand**
- **180,000 cy**
- **50+ bridges in 14 miles**

http://495expresslanes.com/

Mix proportioning technique: sand with high fines

Manufactured sand with high fines (a.k.a microfines, pond fines)

Research



- International Center for Aggregates Research (ICAR)
  - www.icar.utexas.edu
- Established in 1992 by the University of Texas at Austin and Texas A&M University

ICAR study

Type	3/8"	#4	#8	#16	#30	#50	#100	#200
LS-1	100.0	100.0	82.5	56.5	36.6	24.6	17.6	14.3
GT	100.0	100.0	86.0	65.5	47.9	34.3	22.1	13.3
QZ	100.0	100.0	78.0	62.2	50.6	37.3	22.7	13.5
DI	100.0	100.0	77.7	57.6	42.4	31.6	22.6	15.8
DO	100.0	100.0	78.0	55.1	38.8	29.0	21.8	16.7
LS-2	99.9	96.4	66.4	38.0	22.2	13.5	8.0	4.5
LS-3	100.0	97.3	76.0	49.5	33.2	24.0	18.0	13.3
LS-4	100.0	97.0	69.1	39.2	23.9	15.9	11.0	7.4
BA	100.0	100.0	68.1	48.0	35.8	27.2	20.0	14.3
SS	100.0	100.0	72.9	55.8	44.9	31.6	17.0	10.3
ASTM C 33	100	95 to 100	80 to 100	50 to 85	25 to 60	5 to 30	0 to 10	<7

Natural sand: <1.5% minus #200

High fines manufactured sand blended with Natural sand

	HDG #10 Dry Screenings 7/'10	YBP Cecil natural sand '10	Combined Fine Agg (by weight)					ASTM C33 VDOT
			HDG #10 Dry Screenin	*40%*	*30%*	*25%*	*20%*	
			YBP Cecil natural sand	*60%*	*70%*	*75%*	*80%*	
3/8"	100.0	100%		100%	100%	100%	100%	100
#4	96.8	98%		97%	97%	97%	97%	95-100
#8	76.0	81%		***79%***	***79%***	80%	80%	80-100
#16	52.8	67%		61%	63%	63%	64%	50-85
#30	39.1	48%		44%	45%	45%	46%	25-60
#50	29.7	17%		22%	21%	20%	20%	5-30
#100	24.2	4%		***12%***	10%	9%	8%	0-10
#200	**18.9**	0.5%		***8%***	***6%***	5%	4%	0-5
FM	2.81	2.87		2.85	2.85	2.86	2.86	
S.G.	2.77	2.64		2.69	2.68	2.67	2.67	
abs	0.69	1.00		0.88	0.91	0.92	0.94	

<#100: 1400 pcy*.09 = 126 pcy

<#200: 1400 pcy*.05 = 70 pcy

Admixture Dosage Adjustment

- 500pcy cementitious
- Normal setting WR: 3 oz/cwt or 15 oz/cy
- 1400pcy fine agg contributes
  - <#100: 1400 pcy*.09 = 126 pcy
  - <#200: 1400 pcy*.05 = 70 pcy
- New WR dosage:
  - 3*(500+70)/100 = 17.1 oz/cy OR
  - 3*(500+126)/100 = 18.8 oz/cy

Questions?