RECYCLED CONCRETE AGGREGATE (RCA) FOR CONCRETE PAVING

Brett Trautman, P.E.
Physical Laboratory Director

Missouri/Kansas Chapter, ACPA

34th Annual PCCP Conference

February 27, 2014

History

- In Aug. 2010, discussed using RCA on two lift concrete paving project
  - No RCA available
- In June 2012, met w/Millstone Bangert about using RCA
  - Limited reserves remaining in urban quarries
  - Remaining quarries outside the urban area
  - Opening new quarries difficult
- In Aug. 2012, materials delivered to Central Laboratory

History

- In Sept. 2012, concrete batching started
- Evaluating fresh & harden properties
- Batching done in 3 phases
- In Jan. 2013, met w/Missouri University of Science & Technology about conducting research
- In Feb. 2013, met w/St. Louis District to discuss project use
- Ramp on Mississippi River Project
- In Aug. 2013, selected second project
- Off-ramp from I-70 in St. Charles Co.

Materials

- Recycled Concrete Aggregates
  - Processed at Lambert Airport
  - Coarse & fine fractions
  - Believe coarse aggregates from a St. Louis Limestone

- Virgin Coarse Aggregate
  - 1 in. maximum size
  - St. Louis Limestone
- Virgin Fine Aggregate
  - Class A sand
  - Missouri River

Materials

- Hydraulic Cement
  - Type I portland cement
  - Holcim
- Fly Ash
  - Class C
  - Labadie Power Plant
- Admixtures
  - Daravair 1400
  - Darcem 65

Coarse Aggregate

Material	1” Max. L.S.	Coarse RCA
Bulk Sp. Gr.	2.652	2.396
Absorption	0.8	3.5
LA Abrasion	24	33
Soundness	3	32
Micro-Deval	15.0	14.4

	Sieve	% Passing	% Passing
Gradation	1 in.	100	100
	3/4 in.	88.5	80.3
	1/2 in.	40.5	31.1
	3/8 in.	20.1	16.8
	#4	3.1	3.3
	#8	1.8	1.8
	#200	1.4	0.7

Fine Aggregate

Material	Natural Sand	Fine RCA
Bulk Sp. Gr.	2.628	2.277
Absorption	0.2	5.8
F.A.A.	38.0	54.3
S.E.	98	75

Gradation	Sieve	% Passing	% Passing
	3/8 in.	100	100
	#4	98.4	98.7
	#8	92.0	77.5
	#16	72.8	55.0
	#30	36.6	35.7
	#50	11.1	20.0
	#100	0.8	11.5
	#200	0.2	7.6

Phases

- Three different phases
- 3 batches per phase
- 3.85 cu. ft. per batch
- Phase One
- Evaluate impact of using RCA
- Same admixture dosages; effect on air & slump
- Phase Two
- Evaluate impact of higher dosages of coarse RCA
- Adjusting admixture dosages to control air & slump
- Phase Three
- Evaluate impact of higher dosages of fine RCA
- Adjusting admixture dosages to control air & slump

Mix Designs
Phase No. 1

Design Criteria	Control Mix	Exp. Mix # 1	Exp. Mix # 2
Cement Amount (lbs.)	545	545	545
w/c Ratio	0.40	0.40	0.40
% Fly Ash	25.0	25.0	25.0
% Fine Agg.	42.5	42.5	42.5
% Coarse RCA Agg.	---	30.0	30.0
% Fine RCA Agg.	---	---	10.0
Design Air Content (%)	6.0	6.0	6.0
Air Entrainment (ozs/cwt)	1.2	1.2	1.2
Water Reducer (ozs/cwt)	3.0	3.0	3.0

Mix Designs
Phase No. 2

Design Criteria	Exp. Mix # 3	Exp. Mix # 4	Exp. Mix # 5
Cement Amount (lbs.)	545	545	545
w/c Ratio	0.40	0.40	0.40
% Fly Ash	25.0	25.0	25.0
% Fine Agg.	42.5	42.5	42.5
% Coarse RCA Agg.	20.0	40.0	60.0
% Fine RCA Agg.	---	---	---
Design Air Content (%)	6.0	6.0	6.0
Air Entrainment (ozs/cwt)	1.2	1.25	1.45
Water Reducer (ozs/cwt)	2.6	2.6	2.0

Mix Designs
Phase No. 3

Design Criteria	Exp. Mix # 6	Exp. Mix # 7	Exp. Mix # 8
Cement Amount (lbs.)	545	545	545
w/c Ratio	0.40	0.40	0.40
% Fly Ash	25.0	25.0	25.0
% Fine Agg.	42.5	42.5	42.5
% Coarse RCA Agg.	30.0	30.0	30.0
% Fine RCA Agg.	5.0	20.0	35.0
Design Air Content (%)	6.0	6.0	6.0
Air Entrainment (ozs/cwt)	1.4	1.8	2.3
Water Reducer (ozs/cwt)	3.0	4.0	5.0

Testing

- Fresh Properties:
- Air Content (AASHTO T 152)
- Slump (AASHTO T 119)
- Unit Weight

Testing

- Harden Properties

Compressive Strength

- AASHTO T 22
- Molded 3 cylinders per test age
- Cylinder size - 4” x 8”
- 1, 2, 7, 28, & 56-day

Rapid Chloride Permeability

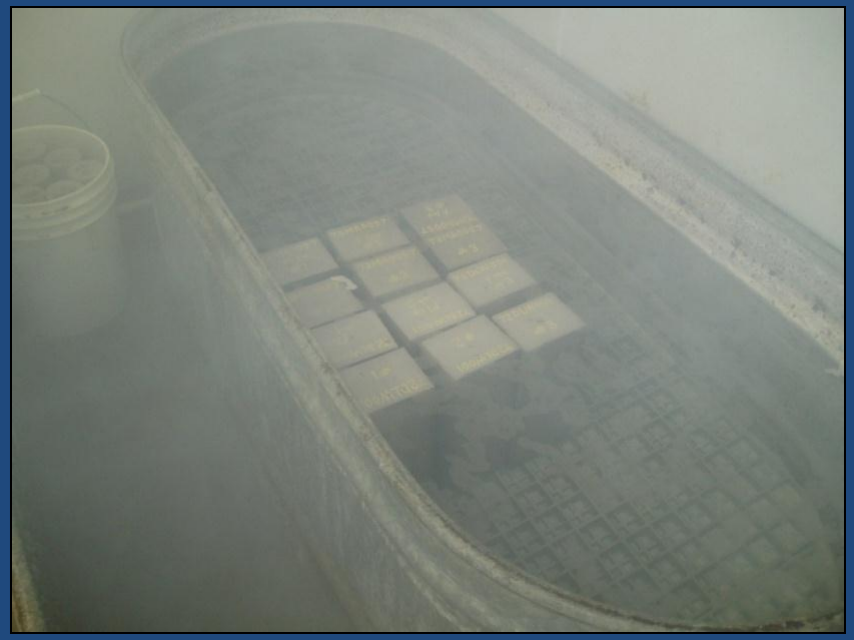
- AASHTO T 277
- Molded 1 cylinder per test age
- Cylinder Size - 4” x 8”
- Test top & middle portion
- 28, 56 & 90 days

Flexural Strength

- AASHTO T 177
- Molded 3 beams
- 3 1/2” x 4 1/2” x 16” beams
- 35-day break; when freeze/thaw testing started
- Test freeze/thaw beams after testing

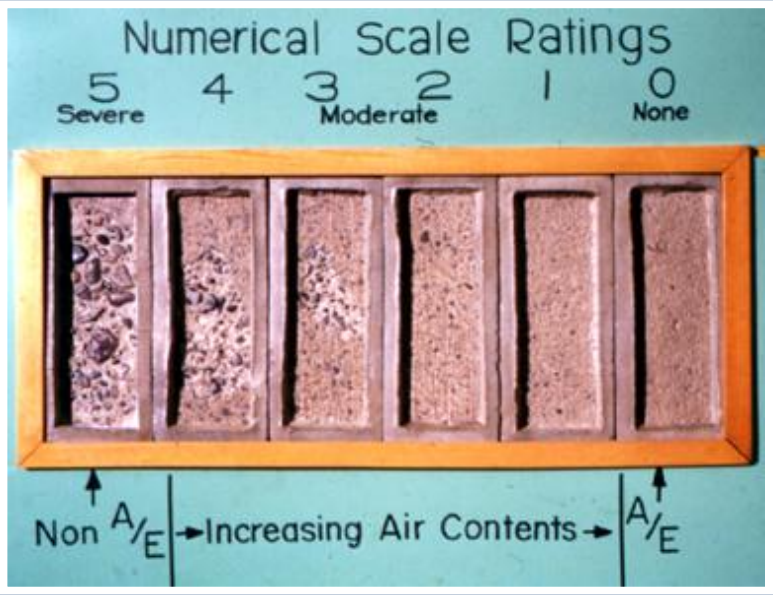
Freeze/Thaw Durability

- AASHTO T 161, Procedure B
- Molded 3 beams
- Beam Size - 3 ½” x 4 ½” x 16”
- 35 days of curing in lime water



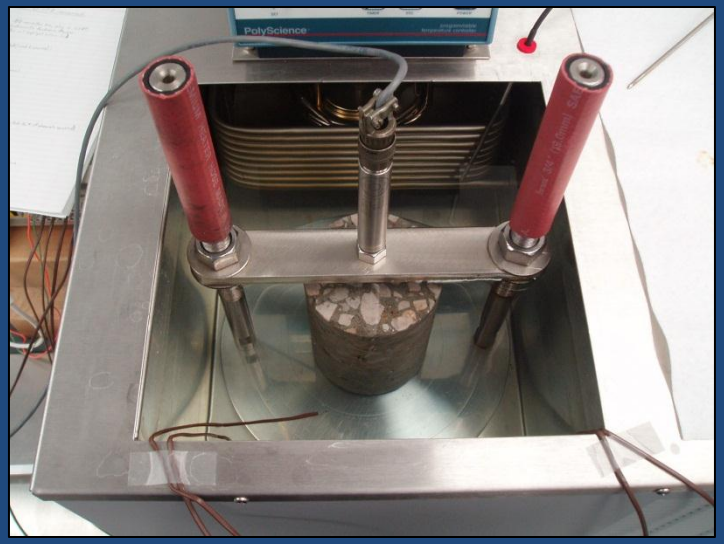
Salt Scaling Resistance

- ASTM C 672
- Molded 2 panels
- Panel Size: 12” x 12” x 3”
- 50 cycles
- 14 days moisture curing & stored in air for 14 days



Coefficient of Thermal Expansion

- AASHTO T 336
- Molded 1 cylinder
- Cylinder Size – 4” x 8”
- Testing after 28 days
- Experience equipment issues



Linear Traverse

- ASTM C 457, Procedure A
  - Manual Method
- Molded 1 cylinder
- Cylinder size – 4” x 8”
- Use in case freeze/thaw durability was low
  - Ensure proper air void system was developed

Test Results

Phase No. 1

Fresh Concrete Properties
Phase No. 1

Mix	RCA Amount	Slump (in.)	Air Content (%)	Unit Wt. (lbs./C.F.)
Control	No RCA used	3 1/2	7.0	143.18
Exp. Mix #1	30% coarse RCA	3 1/2	6.3	143.11
Exp. Mix #2	30% coarse & 10% fine RCA	3	4.6	146.02

Compressive Strength
Phase No. 1

Mix	RCA Amount	Compressive Strength, psi					
		1 day	2 day	7 day	14 day	28 day	56 day
Control	No RCA used	2701	3280	4437	4853	5493	5751
Exp. Mix #1	30% coarse RCA	2558	3520	4716	4944	5860	6146
Exp. Mix #2	30% coarse & 10% fine RCA	2530	3648	4921	5373	6311	6708

Permeability
Phase No. 1

Mix	RCA Amount	Permeability, coulombs		
		28 day	56 day	90 day
Control	No RCA used	1858	1243	963
Exp. Mix #1	30% coarse RCA	1946	1396	989
Exp. Mix #2	30% coarse & 10% fine RCA	2343	1484	1196

Flexural Strength
Phase No. 1

Mix	RCA Amount	Flexural Strength, psi
		35 day
Control	No RCA used	849
Exp. Mix #1	30% coarse RCA	814
Exp. Mix #2	30% coarse & 10% fine RCA	826

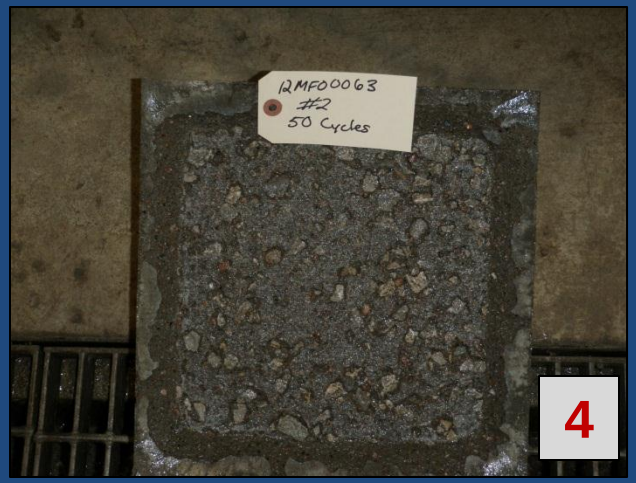
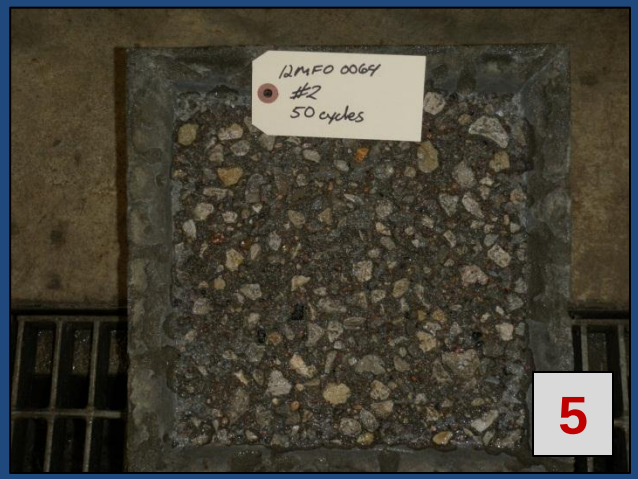
Durability Factor
Phase No. 1

Mix	RCA Amount	Durability Factor
		300 cycles
Control	No RCA used	93.6
Exp. Mix #1	30% coarse RCA	92.2
Exp. Mix #2	30% coarse & 10% fine RCA	92.1

Salt Scale Rating
Phase No. 1

Mix	RCA Amount	Salt Scale Rating
		50 cycles
Control	No RCA used	4
Exp. Mix #1	30% coarse RCA	5
Exp. Mix #2	30% coarse & 10% fine RCA	5

Phase No. 1 – Salt Panels

Control Mix	Exp. Mix No. 1	Exp. Mix No. 2
4	5	5
 4	 5	5

Test Results

Phase No. 2

Fresh Concrete Properties
Phase No. 2

Mix	RCA Amount	Slump (in.)	Air Content (%)	Unit Wt. (lbs./C.F.)
Exp. Mix #3	20% coarse RCA	3	6.4	143.61
Exp. Mix #4	40% coarse RCA	4	5.6	143.51
Exp. Mix #5	60% coarse RCA	2 1/4	4.6	144.19

Compressive Strength
Phase No. 2

Mix	RCA Amount	Compressive Strength, psi					
		1 day	2 day	7 day	14 day	28 day	56 day
Exp. Mix #3	20% coarse	2683	3417	4482	5271	5564	6085
Exp. Mix #4	40% coarse	2487 *(2388)*	3148 *(3022)*	4363 *(4188)*	5295 *(5083)*	5553 *(5331)*	6189 *(5941)*
Exp. Mix #5	60% coarse	2963 *(2696)*	4810* *(4377)*	5431 *(4942)*	5758 *(5240)*	6127 *(5576)*	6843 *(6227)*

** Experimental Mix #5 tested at 5 days*

Permeability
Phase No. 2

Mix	RCA Amount	Permeability, coulombs		
		28 day	56 day	90 day
Exp. Mix #3	20% coarse RCA	2030	1132	1159
Exp. Mix #4	40% coarse RCA	1746	1063	1136
Exp. Mix #5	60% coarse RCA	1868	1026	1027

Flexural Strength
Phase No. 2

Mix	RCA Amount	Flexural Strength, psi
		35 day
Exp. Mix #3	20% coarse RCA	805
Exp. Mix #4	40% coarse RCA	792
Exp. Mix #5	60% coarse RCA	778

Durability Factor
Phase No. 2

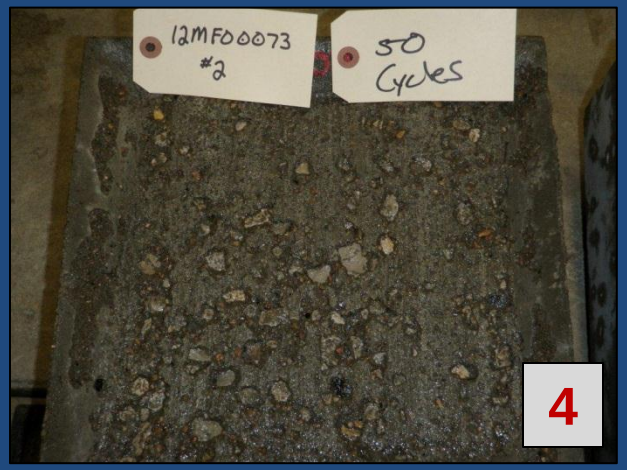
Mix	RCA Amount	Durability Factor
		300 cycles
Exp. Mix #3	20% coarse RCA	93.3
Exp. Mix #4	40% coarse RCA	90.5
Exp. Mix #5	60% coarse RCA	85.8

Salt Scale Rating
Phase No. 2

Mix	RCA Amount	Salt Scale Rating
		50 cycles
Exp. Mix #3	20% coarse RCA	3.5
Exp. Mix #4	40% coarse RCA	3.5
Exp. Mix #5	60% coarse RCA	3

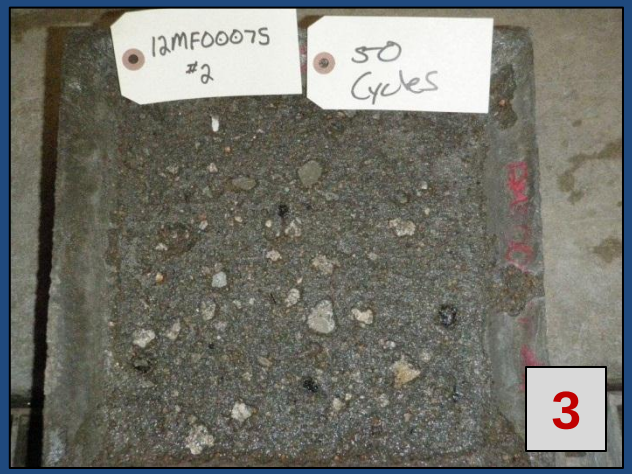
Phase No. 2 – Salt Panels

Exp. Mix No. 3



Exp. Mix No. 4

Exp. Mix No. 5



Test Results

Phase No. 3

Fresh Concrete Properties
Phase No. 3

Mix	RCA Amount	Slump (in.)	Air Content (%)	Unit Wt. (lbs./C.F.)
Exp. Mix #6	30% coarse & 5% fine RCA	2 1/2	5.5	143.37
Exp. Mix #7	30% coarse & 20% fine RCA	2 1/4	5.3	142.80
Exp. Mix #8	30% coarse & 35% fine RCA	2 1/4	5.1	142.52

Compressive Strength
Phase No. 3

Mix	RCA Amount	Compressive Strength, psi					
		1 day	3 day	7 day	14 day	28 day	56 day
Exp. Mix #6	30% coarse & 5% fine RCA	2775	3835	4789	5533	6210	6655
Exp. Mix #7	30% coarse & 20% fine RCA	2581	3534	4704	5513	6026	6500
Exp. Mix #8	30% coarse & 35% fine RCA	2426	3737	4670	5304	5875	6475

Permeability
Phase No. 3

Mix	RCA Amount	Permeability, coulombs		
		28 day	56 day	90 day
Exp. Mix #6	30% coarse & 5% fine RCA	1866	1328	1061
Exp. Mix #7	30% coarse & 20% fine RCA	2128	1629	1112
Exp. Mix #8	30% coarse & 35% fine RCA	2121	1489	1189

Flexural Strength
Phase No. 3

Mix	RCA Amount	Flexural Strength, psi
		35 day
Exp. Mix #6	30% coarse & 5% fine RCA	829
Exp. Mix #7	30% coarse & 20% fine RCA	868
Exp. Mix #8	30% coarse & 35% fine RCA	861

Durability Factor
Phase No. 3

Mix	RCA Amount	Durability Factor
		300 cycles
Exp. Mix #6	30% coarse & 5% fine RCA	90.9
Exp. Mix #7	30% coarse & 20% fine RCA	94.9
Exp. Mix #8	30% coarse & 35% fine RCA	94.1

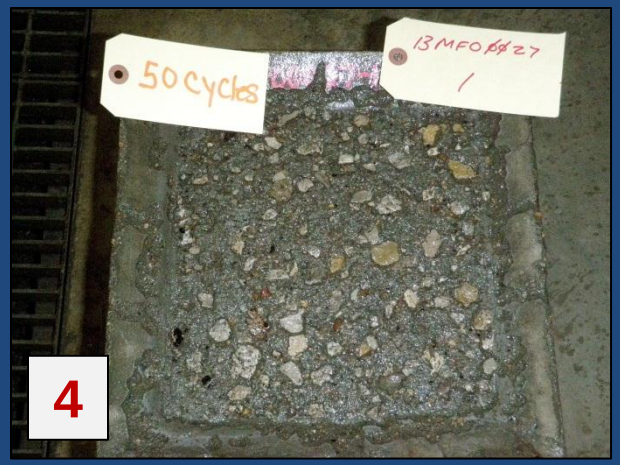
Salt Scale Rating
Phase No. 3

Mix	RCA Amount	Salt Scale Rating
		50 cycles
Exp. Mix #6	30% coarse & 5% fine RCA	4
Exp. Mix #7	30% coarse & 20% fine RCA	4
Exp. Mix #8	30% coarse & 35% fine RCA	4

Phase No. 3 – Salt Panels

Exp. Mix No. 6

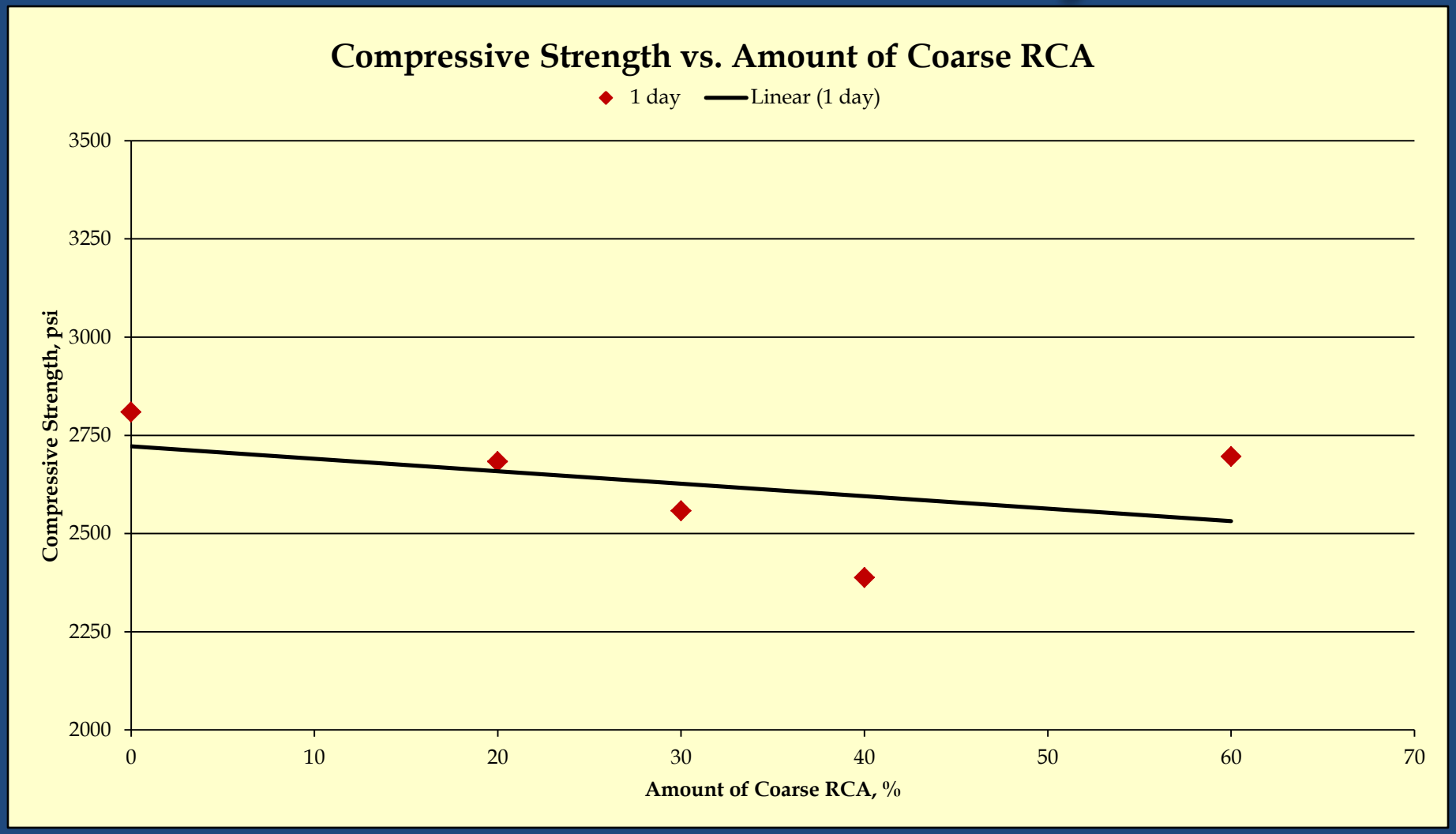
Exp. Mix No. 7



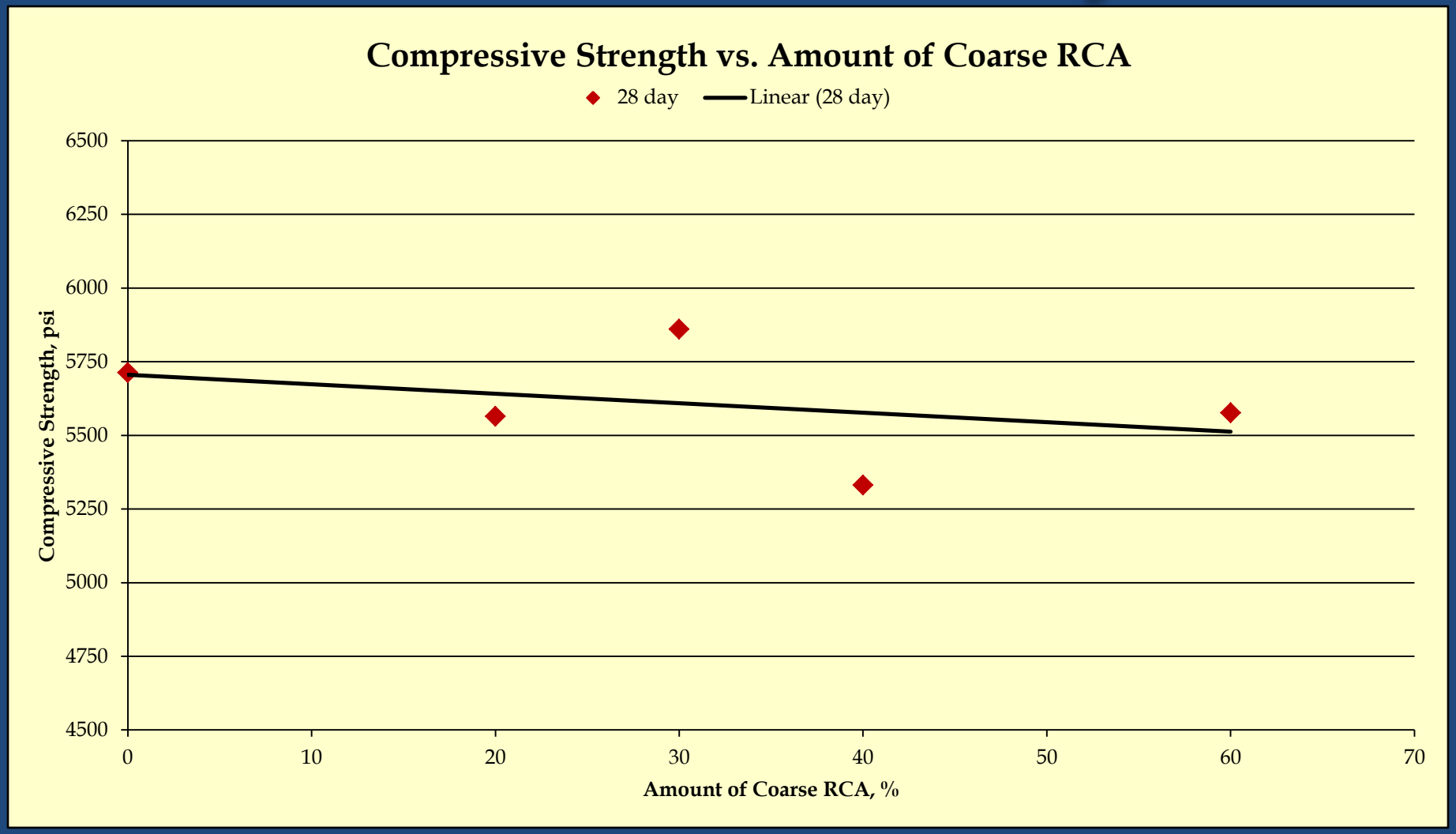
Exp. Mix No. 8

Trends Using Coarse RCA

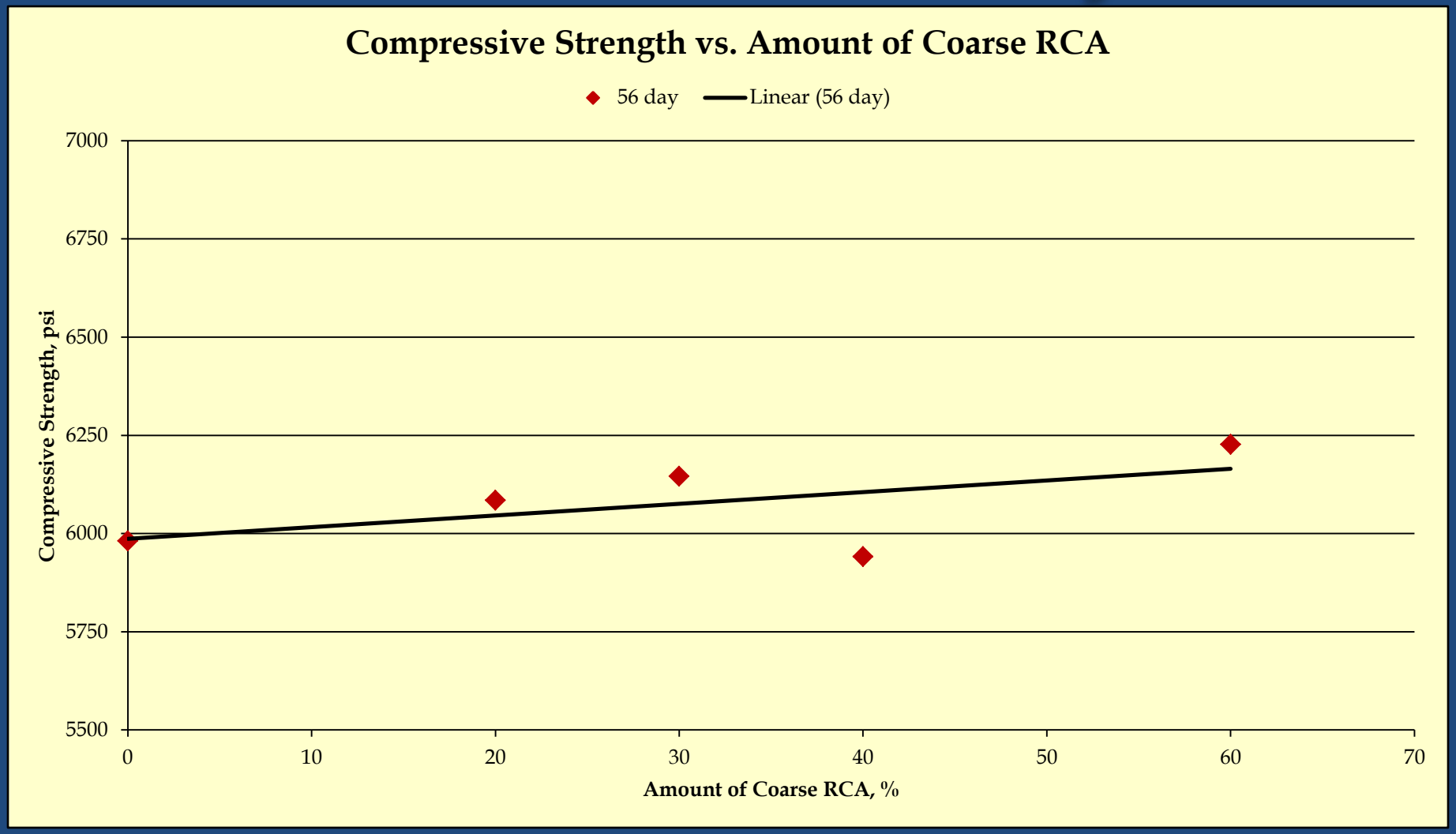
Compressive Strength
Trend Line – 1 day



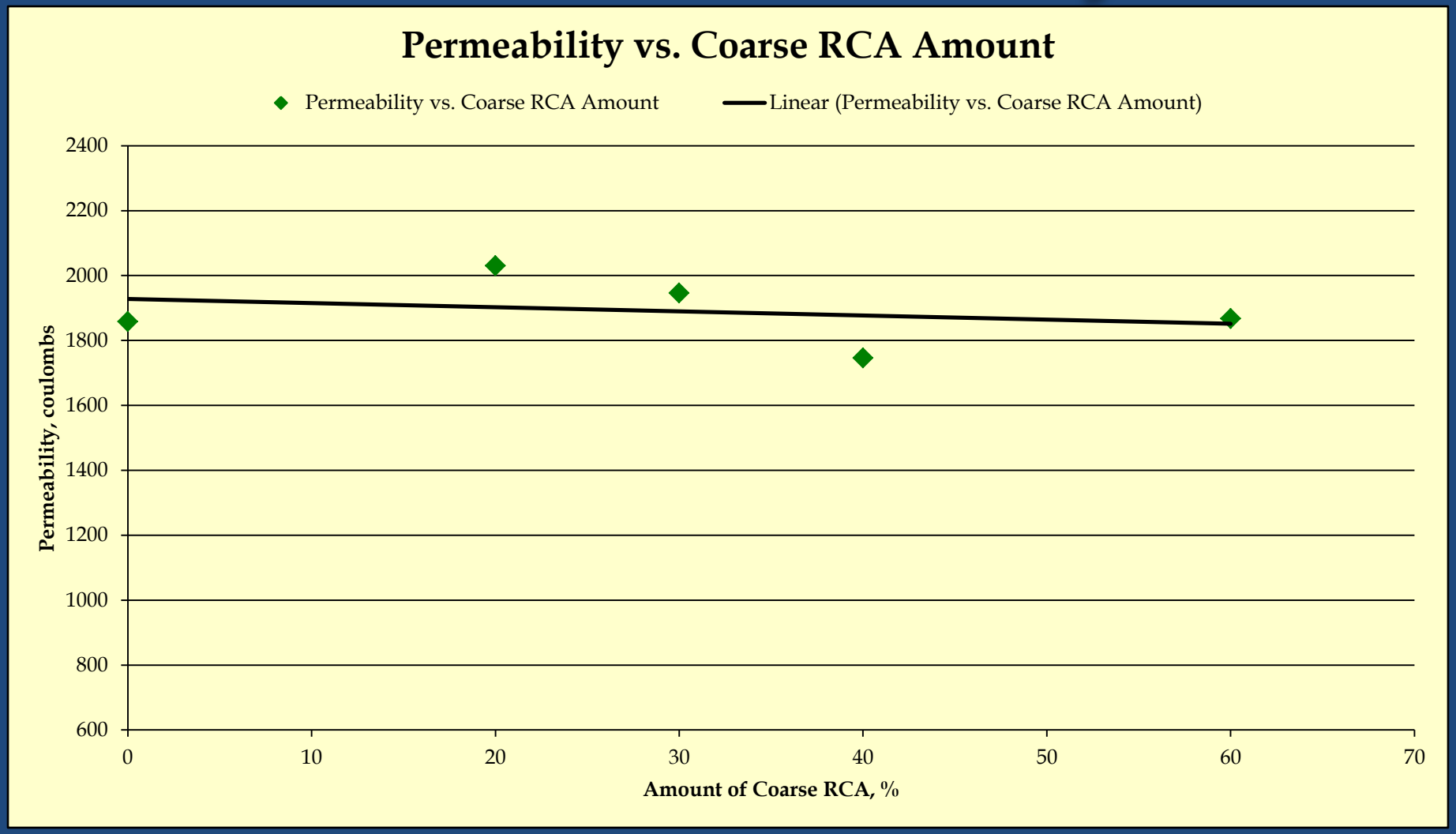
Compressive Strength
Trend Line – 28 day



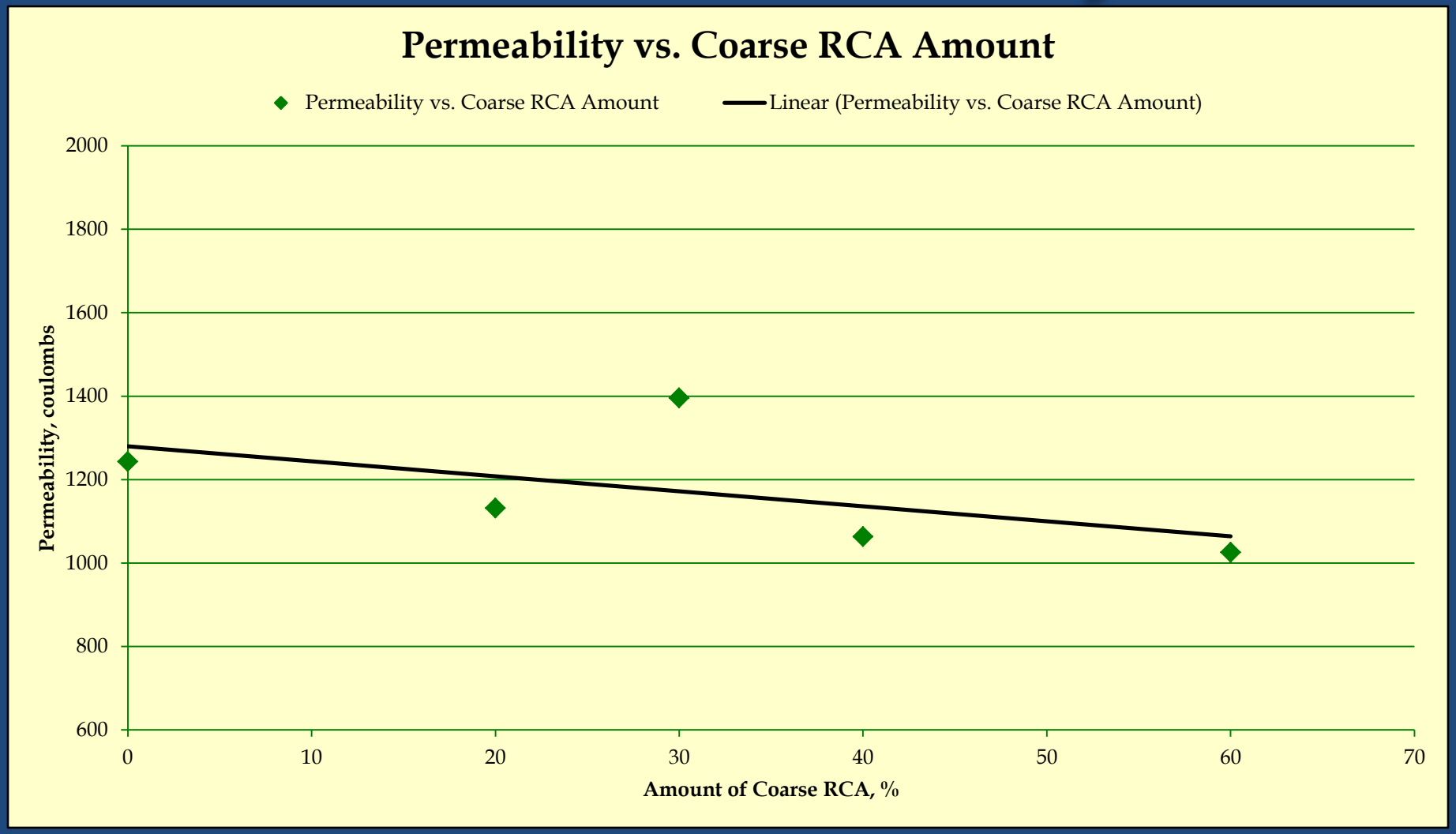
Compressive Strength
Trend Line – 56 day



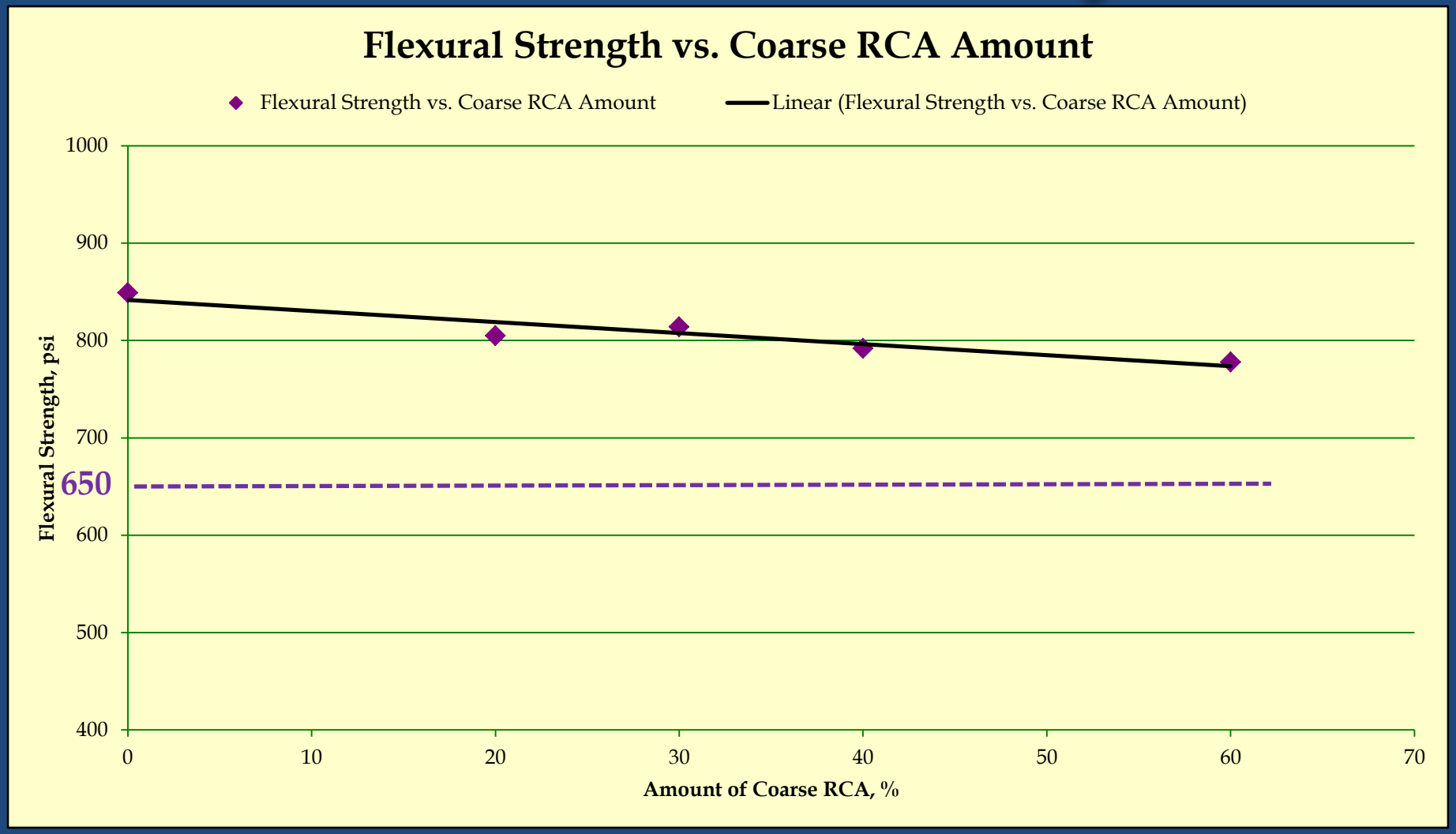
Permeability
Trend Line – 28 day



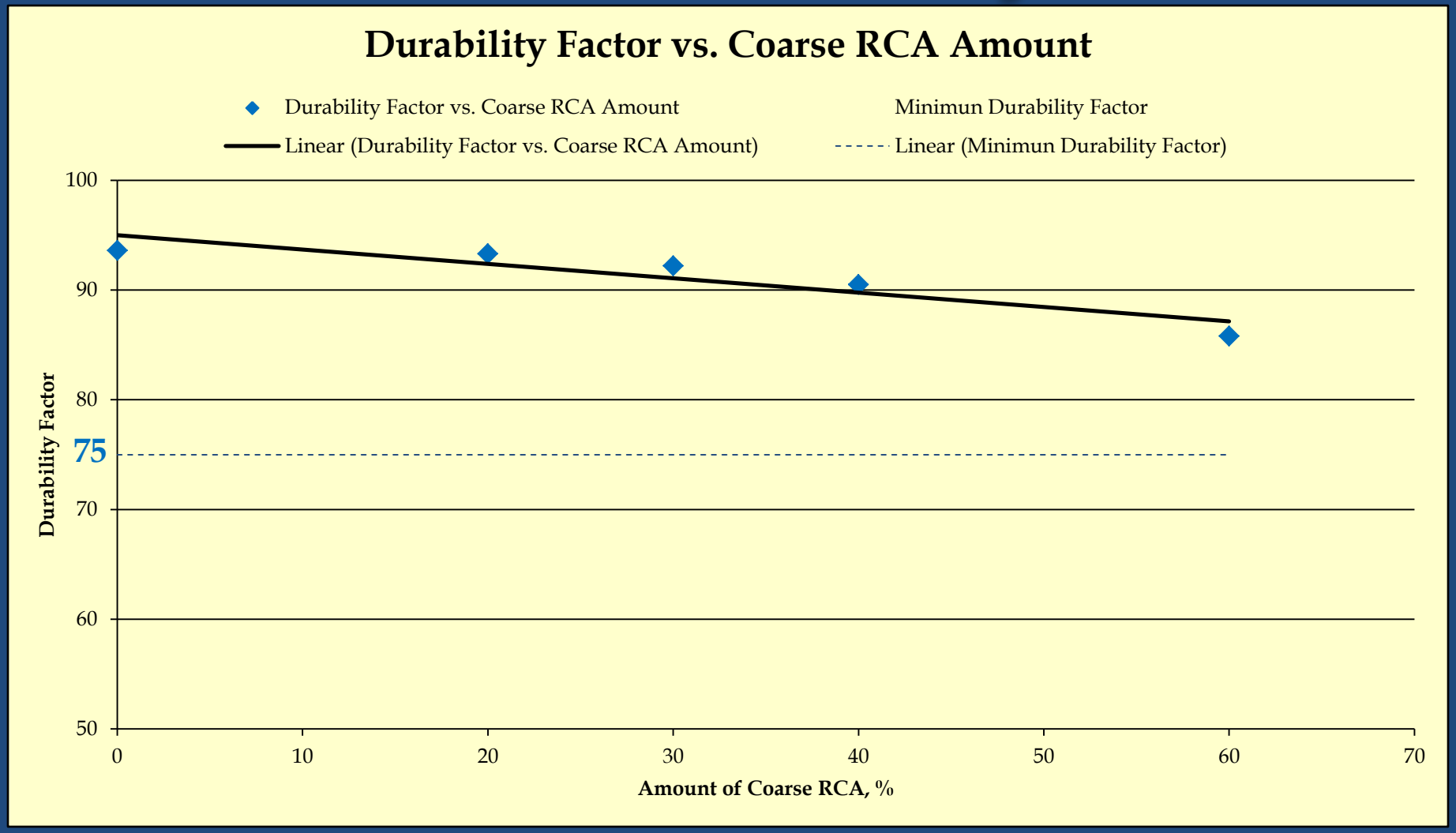
Permeability
Trend Line – 56 day



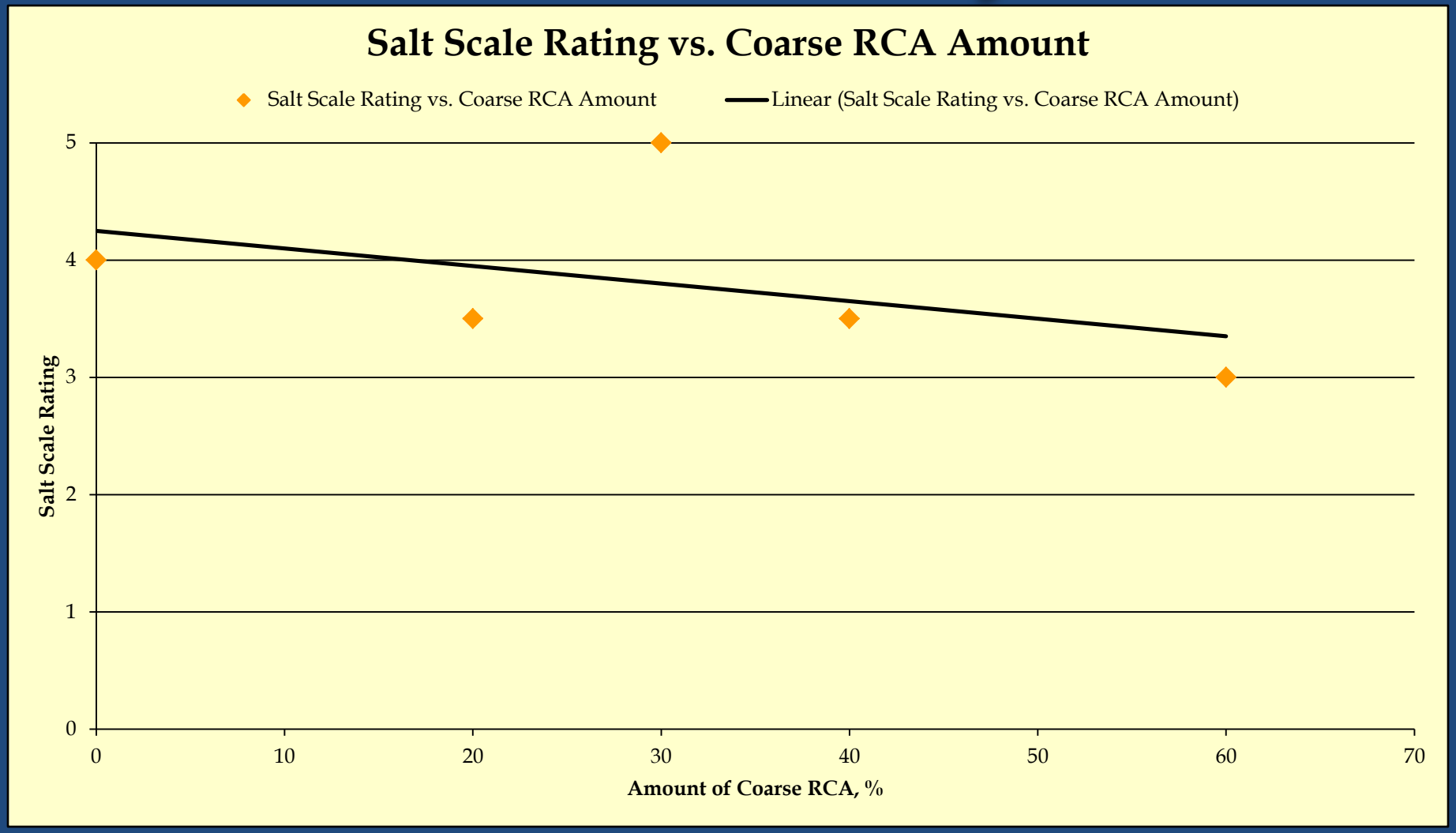
Flexural Strength
Trend Line – 35 day



Durability Factor
Trend Line – 300 cycles



Salt Scale Rating
Trend Line – 50 cycles

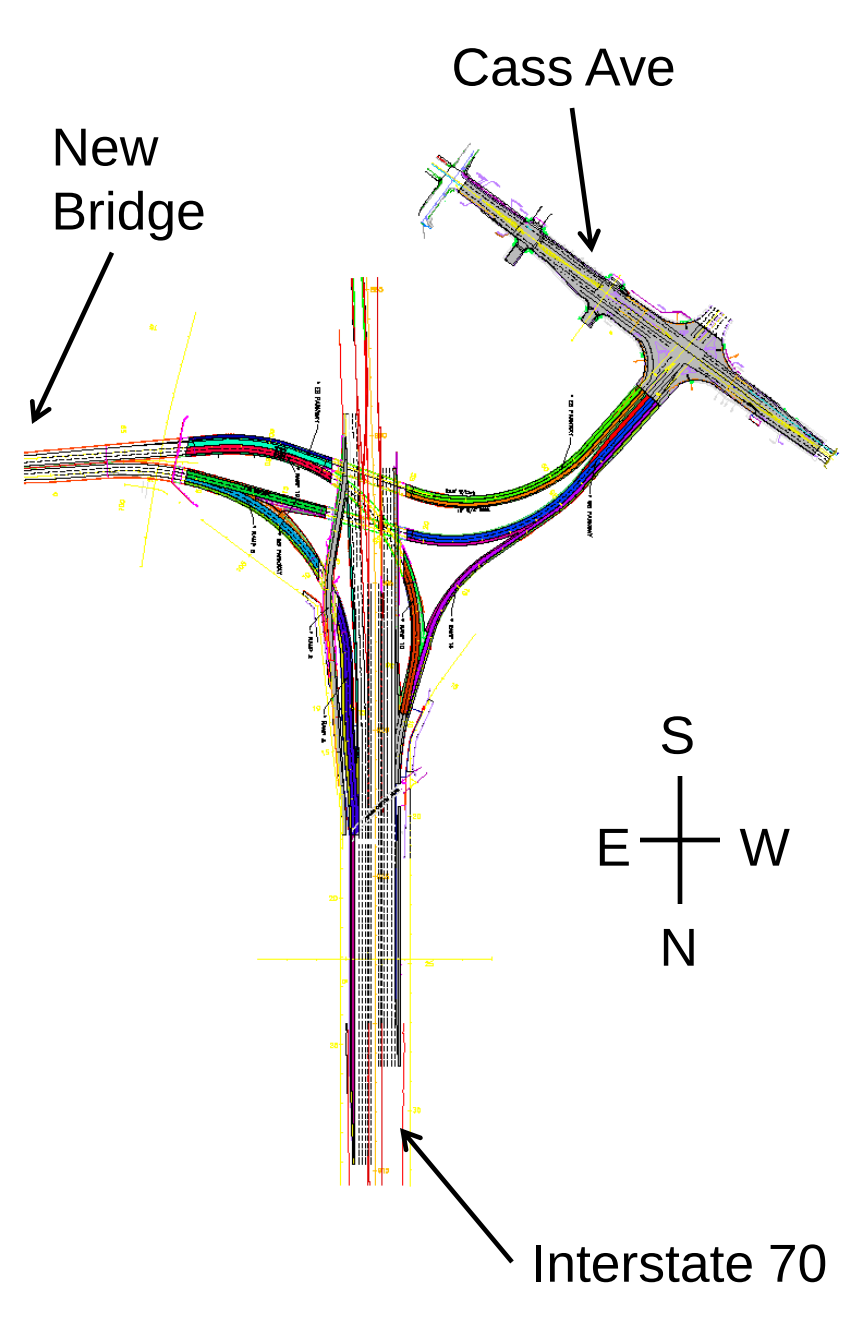


Projects

- Coarse RCA utilized on two projects

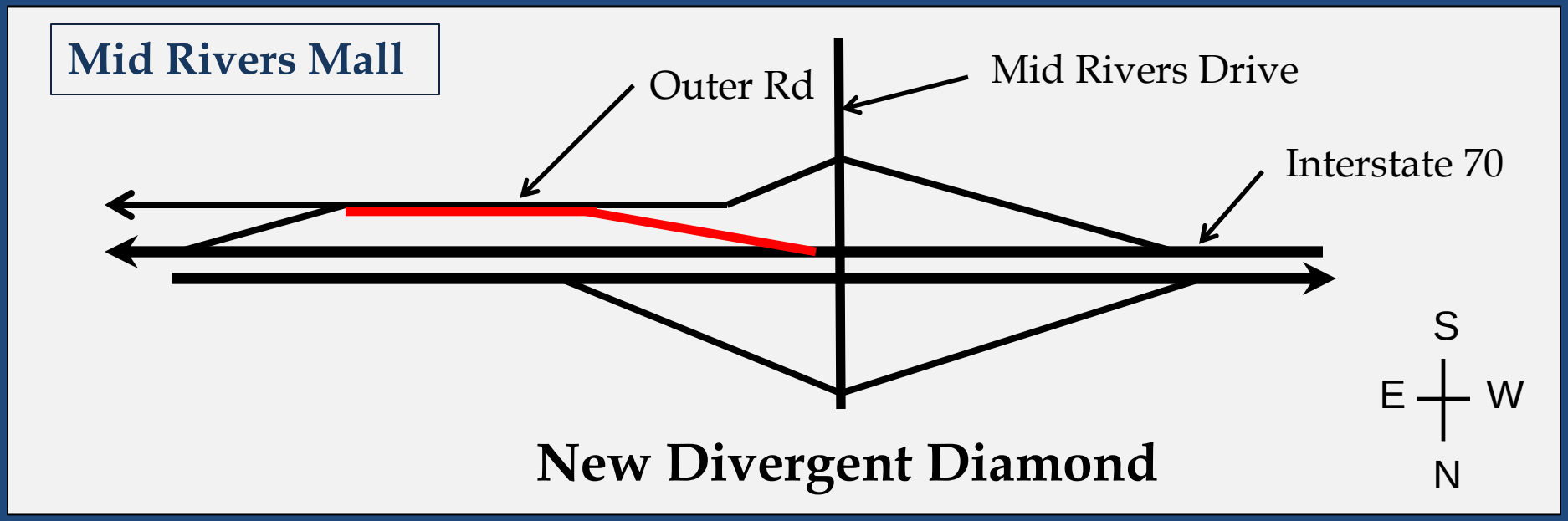
Project No. 1

- Placed on the Mississippi River Bridge project in St. Louis
  - Ramp to new bridge
  - Coarse RCA only
  - Four test sections placed
  - Constructed in April
- Missouri University of Science and Technology conducting research
- MoDOT's mobile laboratory utilized



Project No. 2

- Ramp at I-70 & Mid Rivers Drive in St. Charles Co.
  - Off-ramp from East bound I-70 to outer road **(in red)**
  - Only coarse RCA utilized (*30%*)
  - Coarse RCA from multiple sources
  - Constructed in September
- MoDOT's mobile laboratory utilized



Questions

brett.trautman@modot.mo.gov

(573) 751-1036