Effect of Flat and Elongated Aggregate on SMA Performance

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Outline

- Background- Why is the research needed?
- Objective- What will we do?
- Work Plan- How will mixes be evaluated?
- Results and Conclusions

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Background

- Cost of SMA mix 20-80% higher than conventional dense-graded mix
  - High traffic volume routes
  - Night work with restricted hours
  - Higher asphalt binder demand
  - Special crushed aggregate

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Special Crushed Aggregate

- Special crushing equipment
- Investment/benefit considerations
- High quality aggregates
  - European standards
    - L.A. wear ≤ 30
    - Flat and elongated (F & E) ≤ 20% at 3:1 ratio
  - To resist degradation from studded tires
  - May not be necessary for other countries

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Previous Research

- NCAT Report 00-03
  - Abrasion value is influenced to some degree by particle shape
  - Significant breakdown on No. 4 (4.75 mm) sieve related to particle breakdown at 3:1 ratio
  - Concluded upper limit of F & E between 30-50 may be needed

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Previous Research (Continued)

- Oduroh- Increases up to 40% F & E at 3:1 ratio did not adversely affect performance of Superpave mixes
- Barksdale- Related particle breakdown to both particle shape and L.A. abrasion loss

Barksdale Recommendation (1992)

L.A. Abrasion % Loss	F & E Limit (3:1 Ratio)
≤ 45	≤ 20
≤ 40	≤ 25
≤ 35	≤ 35
≤ 30	≤ 40
≤ 25	≤ 45

Objective

- Evaluate the performance of SMA mixes with different F & E aggregate
- Determine how critical this aggregate property is for SMA performance

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Work Plan

- 5 aggregate sources
  - 3 produce SMA and non-SMA stone
  - 2 do not meet 20% at 3:1 Ratio
- Lab tests
  - F & E Comparison
  - Cantabro loss- cohesion/resistance to raveling
  - Degradation (100 grations)
  - Rut testing- APA
  - Moisture susceptibility

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F & E Properties

Quarry	Aggregate	% F & E 5:1 (GDT 129)	% F & E 3:1 (GDT 129)	% F & E 3:1 (ASTM D4791)
A	SMA 7	0.5	19.7	8.4
	7	1.4	25.5	17.3
	89	2.2	23.9	13.1
B	SMA 7	0.3	17.0	6.8
	7	0.1	19.9	9.5
	SMA 89	0.0	18.2	7.0
	89	0.0	19.2	10.2
C	SMA 7	0.0	15.5	9.1
	7	0.0	23.3	15.7
	89	3.0	30.4	17.8
D	7	6.5	38.9	26.5
	89	3.8	20.7	20.9
E	7	6.2	43.6	31.5
	89	1.9	31.6	16.8

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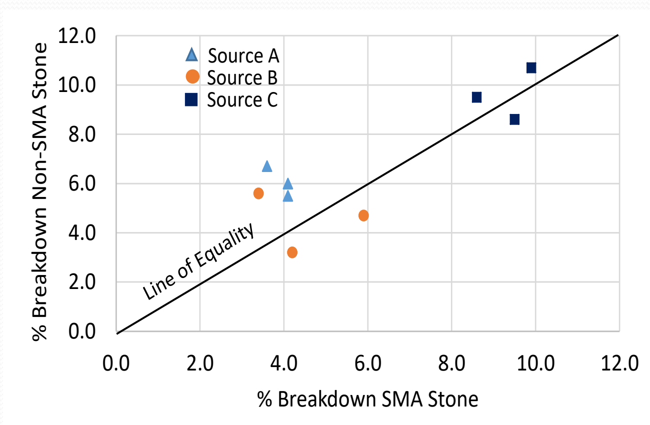
Aggregate Degradation



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Degradation (Difference from Control)

Percent Passing

Sieve Size	Agg. A SMA	Agg. A Non-SMA	Agg. B SMA	Agg. B Non-SMA	Agg. C SMA	Agg. C Non-SMA	Agg. D Non-SMA	Agg. E Non-SMA
No. 4	4.0	6.1	4.5	4.5	9.3	9.6	3.0	1.8
No. 8	2.1	3.6	2.9	3.3	6.7	6.4	1.5	2.2
No. 200	0.0	0.6	0.0	0.3	0.6	0.5	0.1	0.3

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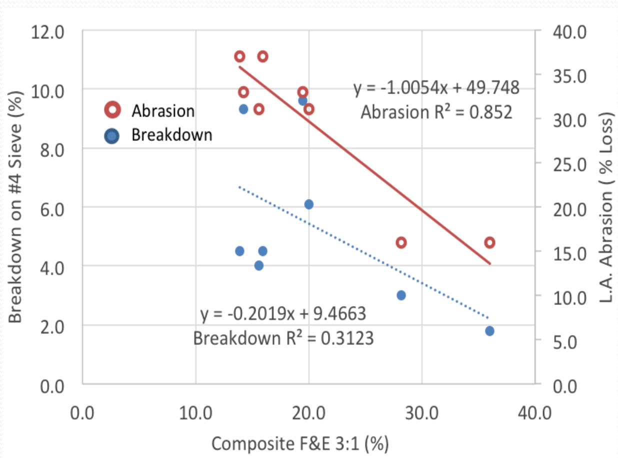
Effect of F&E



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Mix Design Verification

Property	Agg. A SMA	Agg. A Non-SMA	Agg. B SMA	Agg. B Non-SMA	Agg. C SMA	Agg. C Non-SMA	Agg. D Non-SMA	Agg. E Non-SMA
Composite F&E	15.6	20.0	13.9	15.9	14.2	19.5	28.2	36.0
L.A.	31	31	37	37	33	33	16	16
Opt. AC,%	6.4	6.2	6.5	6.2	6.6	6.6	7.1	8.3
VMA	18.2	18.0	18.5	17.7	18.6	18.5	19.8	21.5

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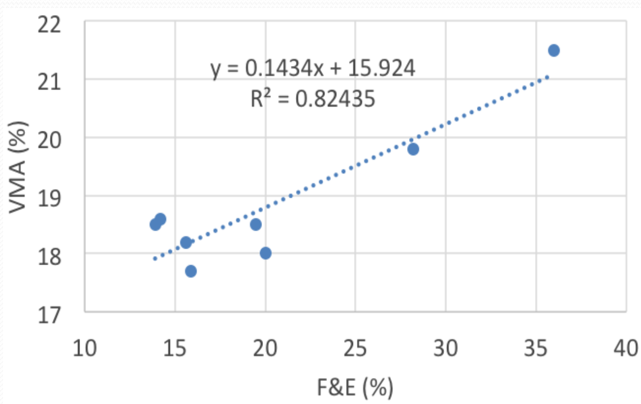
Effect of F&E on VMA



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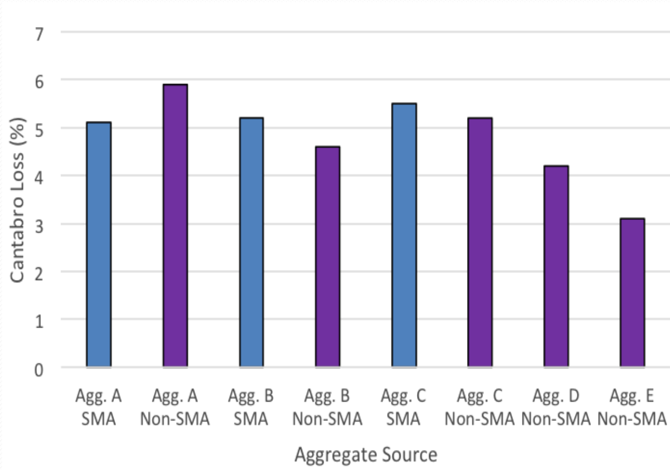
Cantabro Results



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APA Rut Test (AASHTO T340)

- 64°C
- 100 lb load
- 100 psi hose pressure
- 5% air voids
- 8000 cycles
- 5 mm- maximum rut depth allowed

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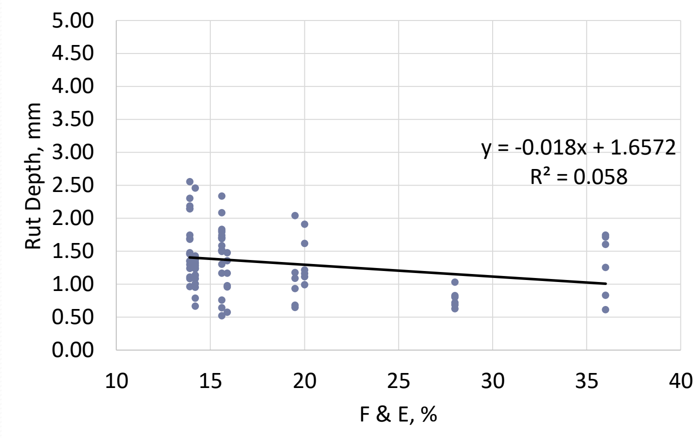
Rutting Results



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Moisture Susceptibility

Aggregate Source	Agg. A SMA	Agg. A Non-SMA	Agg. B SMA	Agg. B Non-SMA	Agg. C SMA	Agg. C Non-SMA	Agg. D Non-SMA	Agg. E Non-SMA
TS-Conditioned (psi)	88.3	89.9	78.3	92.6	85.1	84.7	76.4	77.1
TS-Control (psi)	79.4	104.8	72.5	93.7	78.8	77.6	85.2	86.4
TSR, % (≥ 80)	111.3	85.8	108.0	98.8	108.0	109.1	89.6	89.3

Moisture susceptibility
- 6.0% air voids
- Loading rate- 0.065 inches/minute

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Conclusions

- The 3:1 ratio was much more sensitive to F&E than 5:1.
- Previous recommendations of no more than 20% F&E based on a 3:1 ratio have been found to be unnecessarily restrictive.
- Aggregates with high F&E values may perform well if they have low abrasion loss.
- Aggregate breakdown on the No. 4 (4.75 mm) and No. 200 (0.075 mm) sieves is not dependent on F&E alone.
- Aggregate with high F&E aggregate particles generally have higher VMA properties and may require higher binder content.

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Conclusions

- There is no correlation between rut depth and percent F&E.
- Generally, the tensile strength of SMA mixes is not adversely affected by F&E values.

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Recommendations

- The maximum limit (≤ 20% F&E at a 3:1 ratio) that is a standard threshold used by most agencies for SMA aggregate should be reconsidered
- Aggregates meeting Superpave F&E criteria specified in AASHTO M323 at a 5:1 ratio may be acceptable.
- Similar research is needed for quarry sources that may have both high L.A. abrasion loss and a high proportion of F & E aggregate particles to determine if such sources can also provide satisfactory performance.

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Thank You

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