Effect of Flat and Elongated Aggregate and Mineral Filler on SMA Performance

SEAUPG 2016
Corpus Christi, TX

Objective

- Evaluate the performance of SMA mixes with high F&E aggregate
- Determine how critical 20% max F&E at 3:1 ratio is for SMA
- Evaluate available mineral fillers

Literature Review

- Cost of SMA up to 80% higher than Superpave
- Aggregate costs up to twice that of non-SMA
- European requirements due to use of studded tires (may not be applicable to most of U.S.)
- NCAT 00-03: Fatigue resistance improved as F&E increased. Upper limit of F&E should be dependent on L.A. abrasion
- Oduroh, et al (2000): Up to 40% F&E at 3:1 did not adversely affect Superpave

Materials

- Five aggregate sources used
  - 3- Compare results for SMA and Non-SMA stone
  - 2- Non-SMA stone only
- PG 76-22 binder

F & E Properties

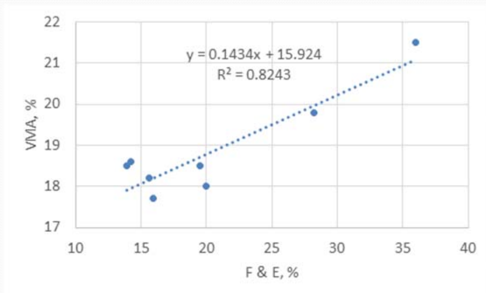
Quarry	Aggregate	% F & E 5:1 (GDT 129)	% F & E 3:1 (GDT 129)	% F & E 3:1 (ASTM D4791)
A	SMA 7	0.5	19.7	8.4
	7	1.4	25.5	17.3
	89	2.2	23.9	13.1
B	SMA 7	0.3	17.0	6.8
	7	0.1	19.9	9.5
	SMA 89	0.0	18.2	7.0
	89	0.0	19.2	10.2
C	SMA 7	0.0	15.5	9.1
	7	0.0	23.3	15.7
	89	3.0	30.4	17.8
D	7	6.5	38.9	26.5
	89	3.8	20.7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

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

* Exceeds maximum limit of 7.5%; 6 trial blends were made for gradation, VCA.

Effect of F&E on VMA



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Test Results

- Cantabro unaged – 50 blow Marshall
- Degradation after 100 gyrations
- APA rutting resistance
  - 64°C
  - 100 lb load
  - 100 psi hose pressure
- Moisture susceptibility
  - 6.0% Va
  - Loading rate- 0.065 inches/minute

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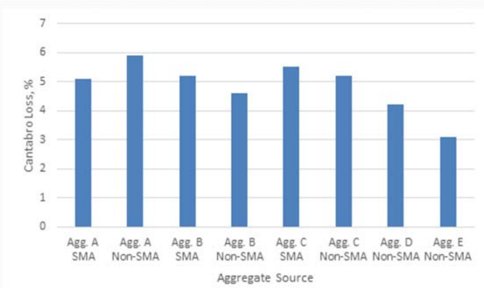
Cantabro Results



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Degradation

Std. Sieve	Metric Sieve	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
3/4"	19.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
1/2"	12.5	0.5	0.6	0.7	-0.5	1.7	1.5	-0.4	-1.9
3/8"	9.5	4.9	7.7	2.5	1.6	6.4	7.4	1.4	-2.0
#4	**4.75**	**4.0**	**6.1**	**4.5**	**4.5**	**9.3**	**9.6**	**3.0**	**1.8**
#8	2.36	2.1	3.6	2.9	3.3	6.7	6.4	1.5	2.2
#16	1.18	1.3	2.5	1.8	2.3	4.4	4.3	0.7	1.4
#30	0.600	0.9	2.1	1.0	1.6	3.2	3.1	0.3	1.0
#50	0.300	0.6	1.7	0.5	1.0	2.1	9.8	0.2	0.6
#100	0.150	0.1	2.2	0.4	0.6	1.3	1.1	0.2	0.4
#200	0.075	0.0	0.6	0.0	0.3	0.6	0.5	0.1	0.3

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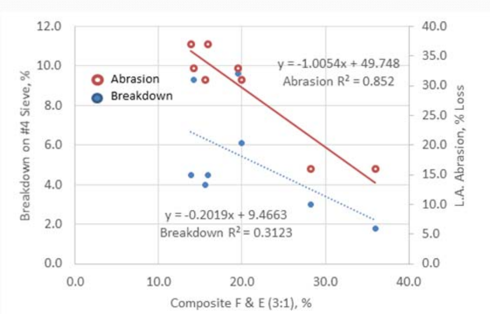
Effect of F&E



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Barksdale Recommendation (1992)

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

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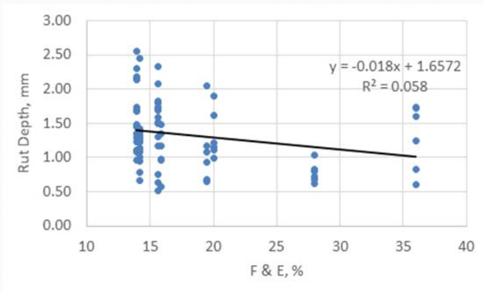
Rutting Results



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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	98.8	108	109.1	89.6	89.3

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Conclusions

- The 3:1 ratio was much more sensitive to F&E.
- 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. (Non-SMA stone showed the greatest rutting resistance.)
- 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.

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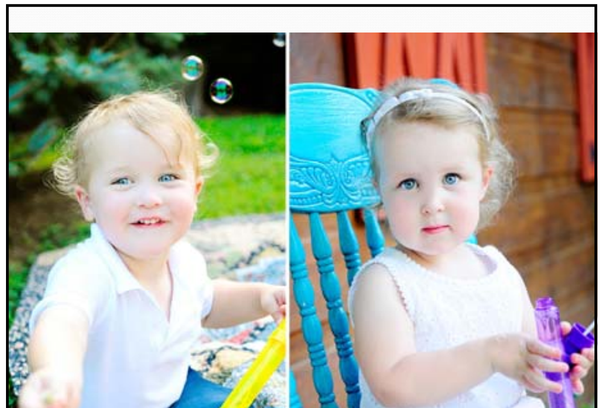

Effect of Mineral Filler on SMA Performance

- Sources of filler
  - 50/50 flyash and baghouse
  - 100% baghouse
  - 100% I-25 marble dust
  - 100% 200W marble dust
- Design verification
- Tensile strength
- Rutting resistance

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Effect of Mineral Filler on Optimum AC

Optimum Asphalt Content for 4.0% Va			
	Mineral Filler		
Agg. Source	50/50	BHF	I-25
Agg. A SMA	6.4	6.4	6.4
Agg. A Non-SMA	6.2	6.4	6.2
Agg. B SMA	6.5	6.5	6.5
Agg. B Non-SMA	6.2	6.5	6.2
Agg. C SMA	6.6	6.8	6.5
Agg. C Non-SMA	6.6	7.0	6.8
Agg. D Non-SMA	7.1	7.4	7.3
Agg. E Non-SMA	N/A	N/A	N/A

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Effect of Mineral Filler on Tensile Strength

Agg. Source	Aggregate Source A				Aggregate Source B				Aggregate Source C				Aggregate Source D	Aggregate Source E
Filler	50/50	I-25	200W	Non-SMA 50/50	50/50	I-25	200W	Non-SMA 50/50	50/50	I-25	200W	Non-SMA 50/50	Non-SMA 50/50	Non- SMA 200W
Control psi	80.2	91.9	93.2	102.0	73.6	84.2	86.8	94.1	81.4	90.6	95.2	74.8	84.2	79.4
	74.5	90.2	99.0	98.1	77.8	84.1	89.1	91.8	79.7	78.0	86.9	85.7	81.2	83.2
	83.3	95.2	97.3	114.3	66.2	82.3	90.2	95.2	75.4	86.2	89.4	72.4	90.2	96.5
Avg.	79.4	92.4	96.5	104.8	72.5	83.5	88.7	93.7	78.8	85.0	90.5	77.6	85.2	86.4
Conditioned psi	84.1	80.8	91.0	98.1	79.8	82.2	82.9	88.5	86.9	85.0	81.8	97.3	72.4	70.5
	94.9	92.8	82.3	87.2	80.2	83.4	83.3	95.1	81.9	84.6	82.6	83.6	76.6	80.6
	85.9	83.1	84.0	84.4	75.0	88.6	88.9	94.2	86.6	87.5	88.4	73.4	80.1	80.3
Avg.	88.3	85.5	85.8	89.9	78.3	84.7	85.0	92.6	85.1	85.7	84.3	84.7	76.4	77.1
TSR,%	111.3	92.5	88.9	85.8	108	101.4	95.8	98.8	108	100.9	93.1	109.1	89.6	89.3

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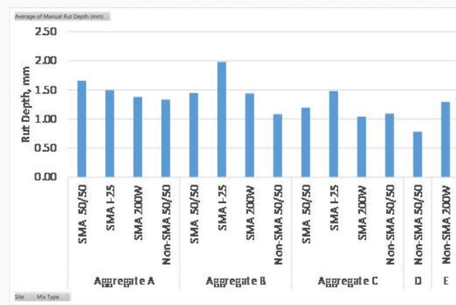
Effect of Filler on Rut Depth



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Conclusions and Recommendations

- The mineral filler products used in this study had little effect on optimum asphalt content.
- 50/50 blend had lowest control strength.
- Mixes with the highest F&E properties had the lowest conditioned strength but the differences were not significant.
- Both I-25 and 200W marble dust may be used as an acceptable mineral filler in SMA mixes with no appreciable difference in mixture volumetrics or anticipated performance.

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Thank You

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