ARC
Asphalt Research Consortium

Subtask E2b-1.a:

Impact of current extraction techniques on properties of extracted RAP aggregates

University of Nevada Reno and NCAT

HMA Recycling Expert Task Group
May 20, 2010, Auburn, Alabama

Develop a System to Evaluate the Properties of RAP

Objective

- **Evaluate impact of current extraction techniques on properties of extracted RAP aggregates.**

- **Extract aggregates from Lab-produce RAP mixes using:**
  - **Centrifuge (Trichloroethylene)**
  - **Reflux (Trichloroethylene)**
  - **Ignition oven**

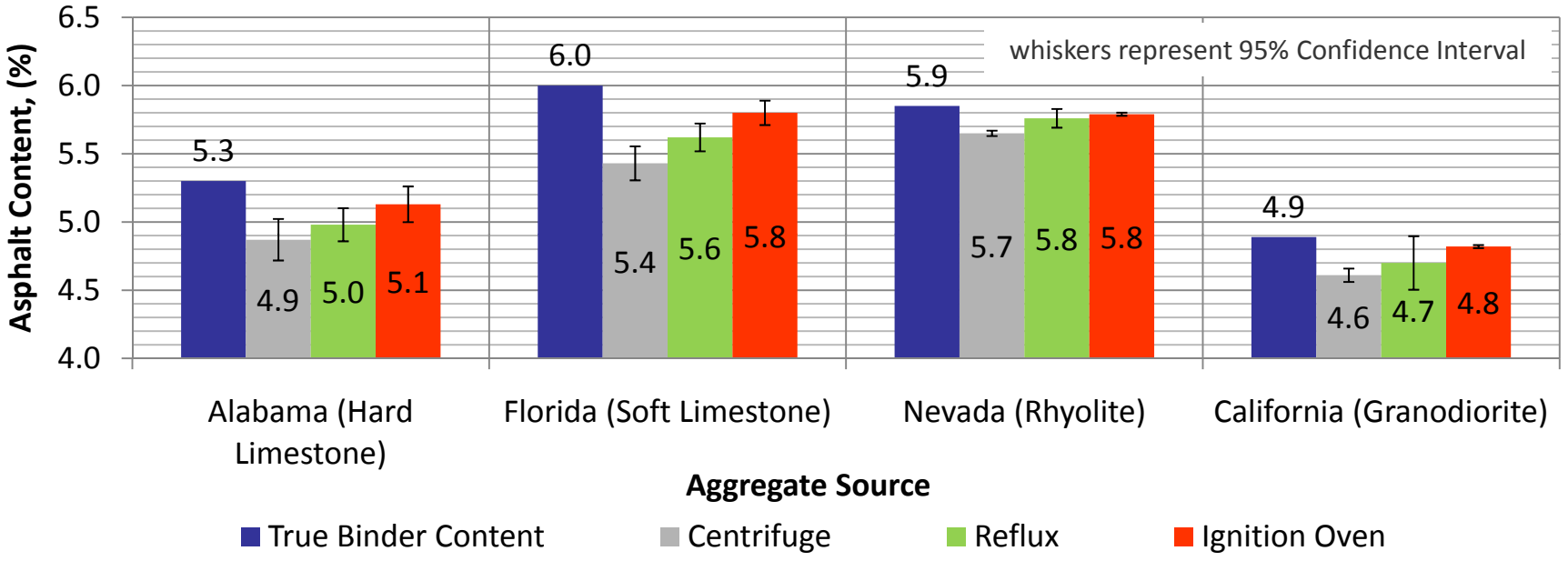
Develop a System to Evaluate the Properties of RAP Aggregate Sources

- Nevada: Rhyolite (UNR)
- California: Granodiorite (UNR)
- Alabama: Hard Limestone (NCAT)
- Florida: Soft Limestone (NCAT)

Develop a System to Evaluate the Properties of RAP
Lab Produced RAP

- SP mix design: intermediate gradation.
- Subject ***loose*** samples to STOA (4 hrs at 275°F) followed by LTOA (5 days at 185°F).
- Extract aggregates from aged loose specimens.
- Measure extracted aggregates physical properties.

Develop a System to Evaluate the Properties of RAP Extracted Binder Contents



Ignition oven is generally the closest to the true binder content, followed by reflux, & lastly centrifuge.

Develop a System to Evaluate the Properties of RAP

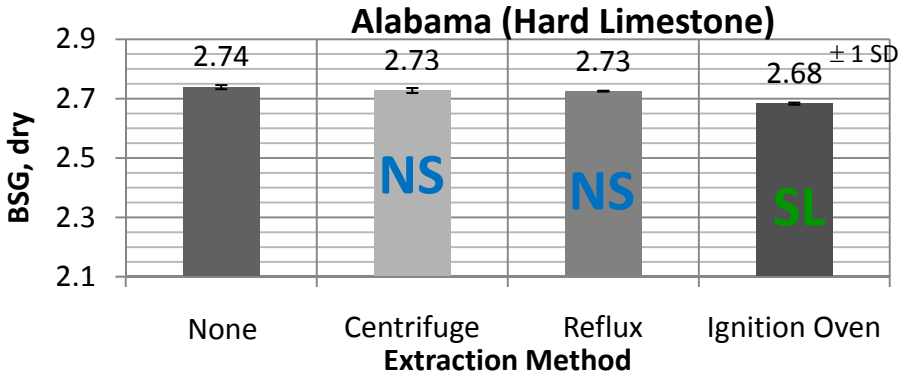
Measured Aggregate Properties

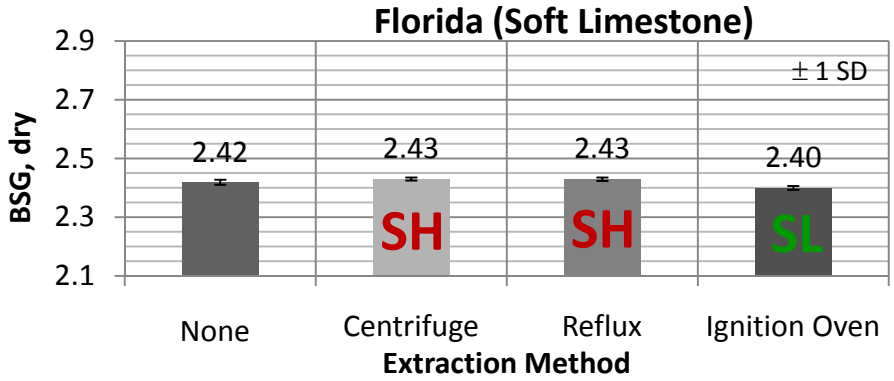
Property	Specification
Sieve Analysis	AASHTO T 27, T30
Coarse Aggregate Durability	AASHTO T 210
Fine Aggregate Durability	AASHTO T 210
Sand Equivalent	AASHTO T 176
LA Abrasion	AASHTO T 96
Specific Gravity and Absorption of Coarse Aggregate	AASHTO T 85
Specific Gravity and Absorption of Fine Aggregate	AASHTO T 84
Fine Aggregate Angularity	AASHTO T 304
Fractured Faces	ASTM D 5821
Percent of Loss in the Microdeval	ASTM D 7428
Soundness	AASHTO T 104
Aggregate Imaging System (AIMS)	--

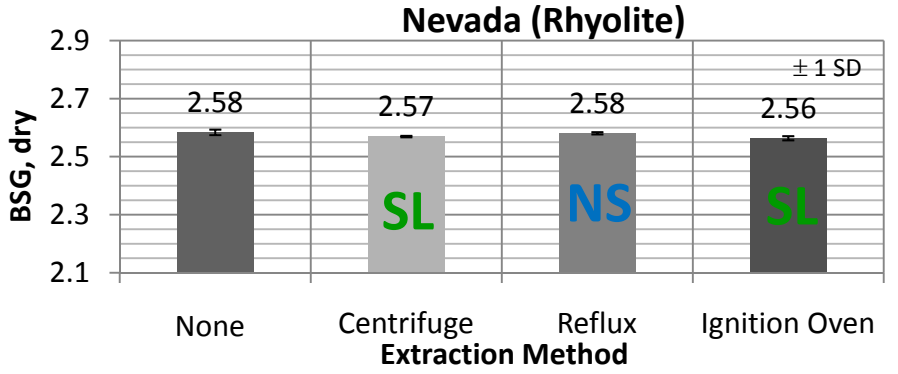
Develop a System to Evaluate the Properties of RAP
Focus of the Presentation

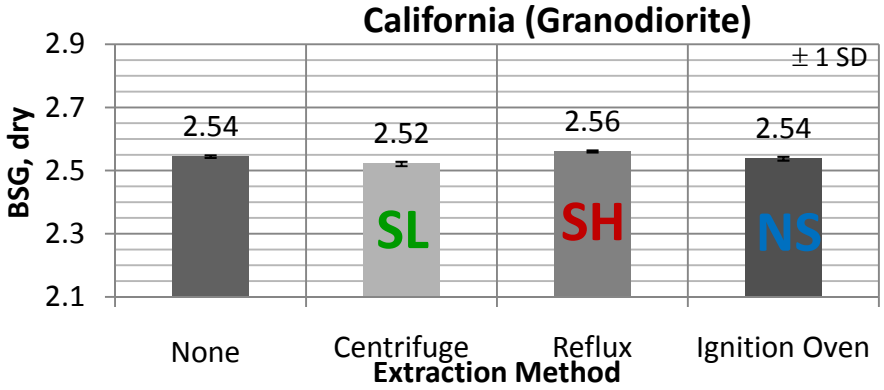
- **BSG & Absorption of coarse aggregates**
- **BSG & Absorption of fine aggregates**
- **Consequences of extraction method on SP mix design.**
- **Effect of RAP aggregate SG on VMA**

Develop a System to Evaluate the Properties of RAP Coarse Aggregate – Bulk Dry Specific Gravities (Gsb)

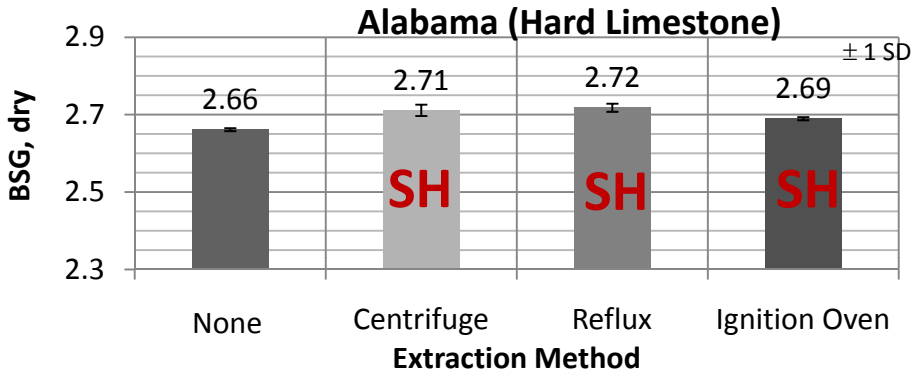


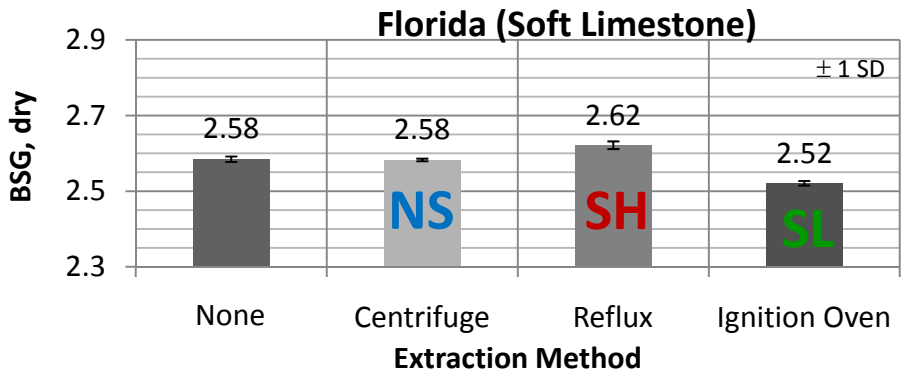


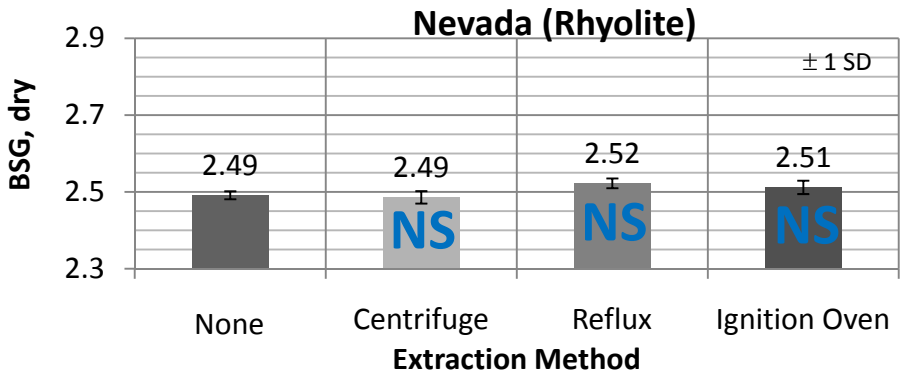


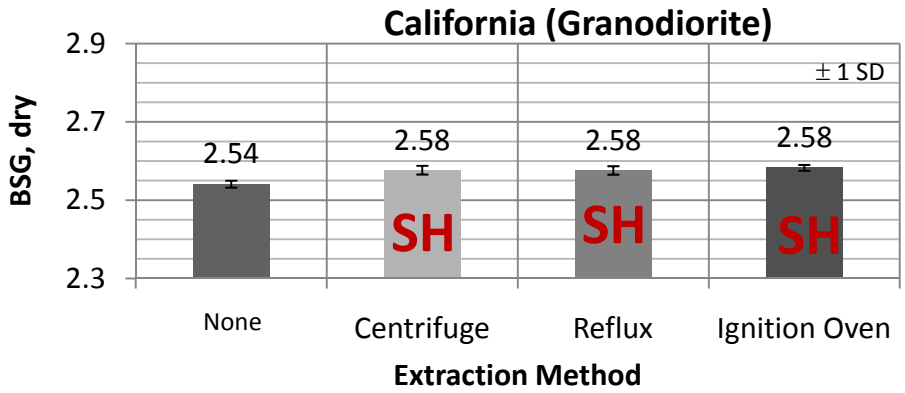


Develop a System to Evaluate the Properties of RAP Fine Aggregate – Bulk Dry Specific Gravities (Gsb)

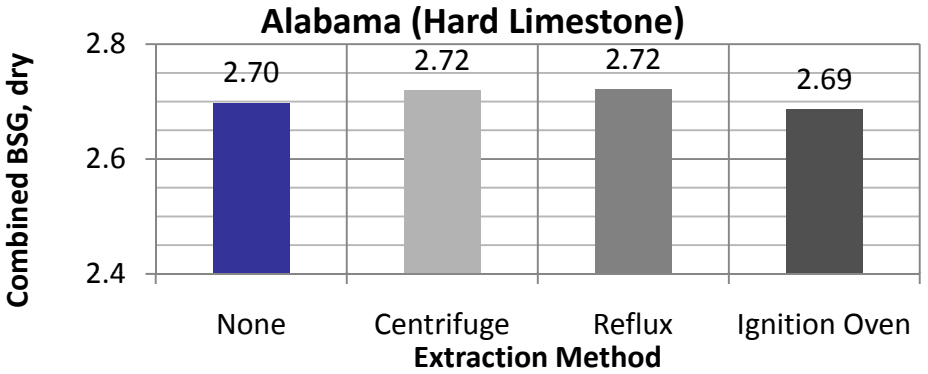


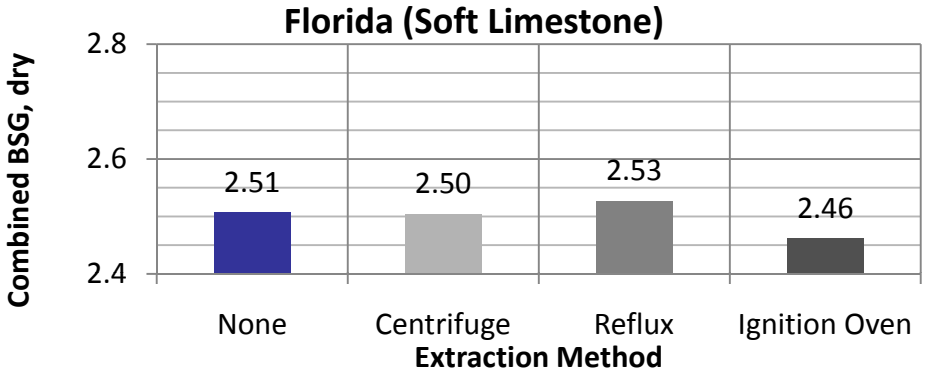


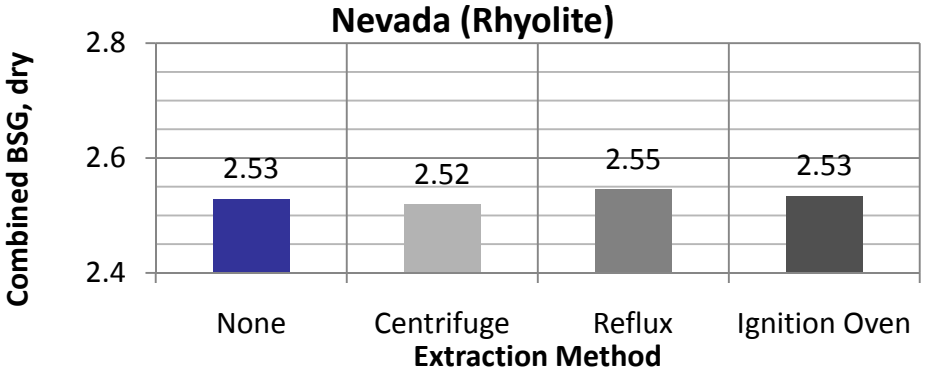


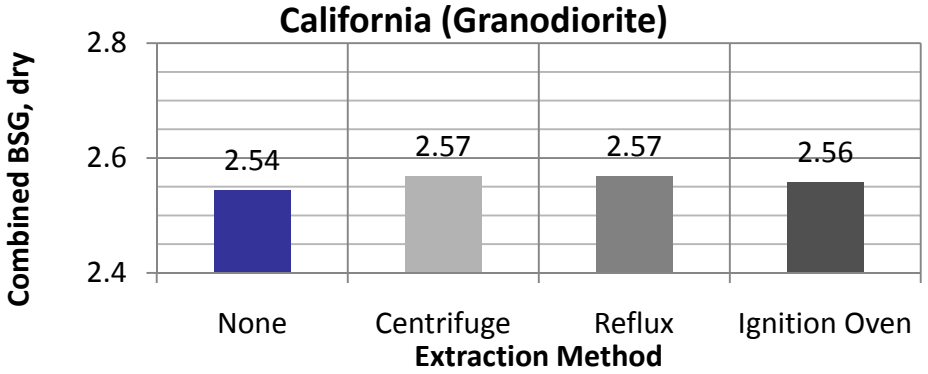


Develop a System to Evaluate the Properties of RAP Combined Aggregate – Bulk Dry Specific Gravities (Gsb)



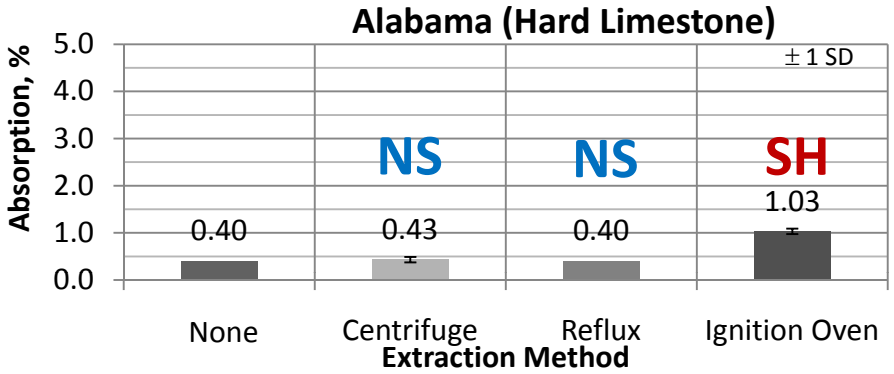


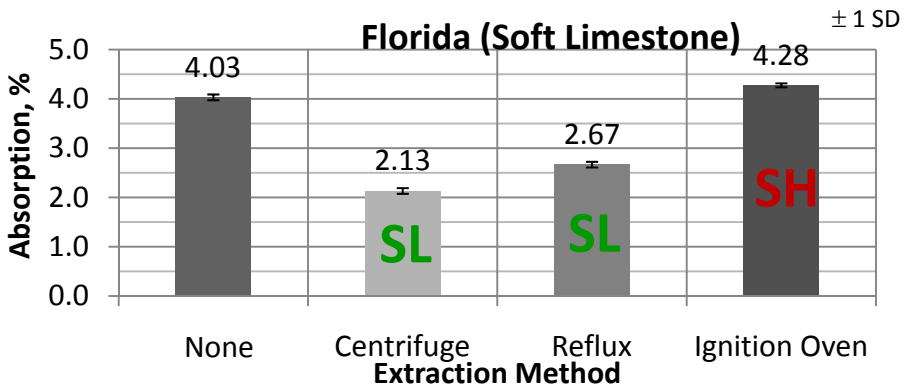


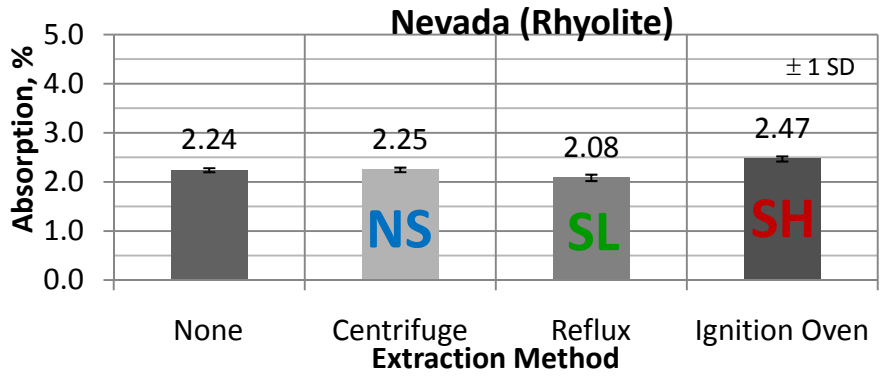


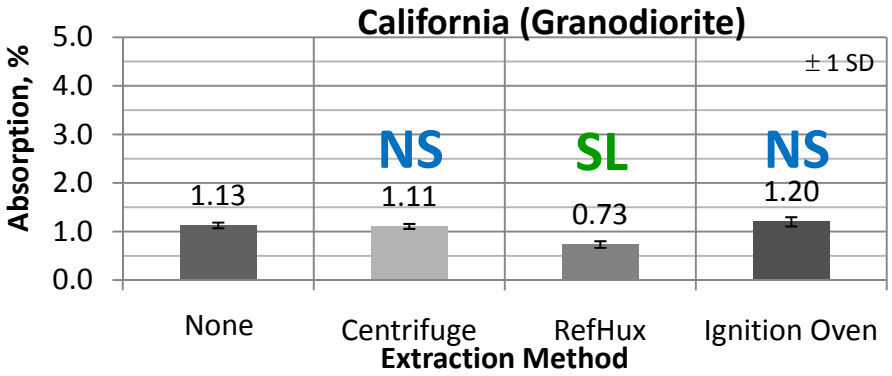
Develop a System to Evaluate the Properties of RAP

Coarse Aggregate – Absorption

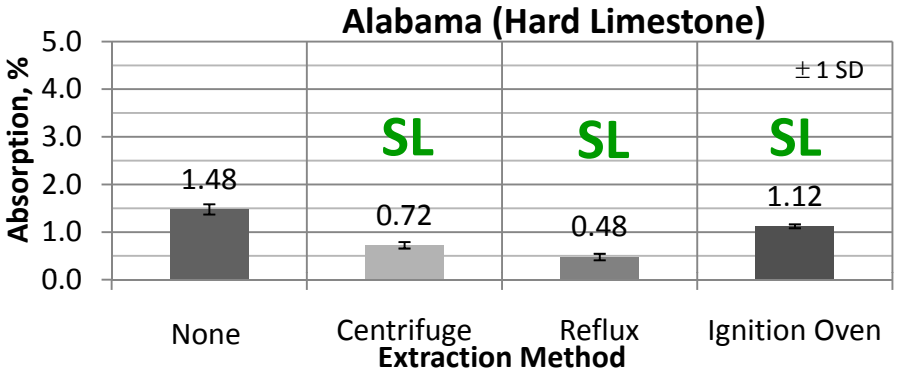


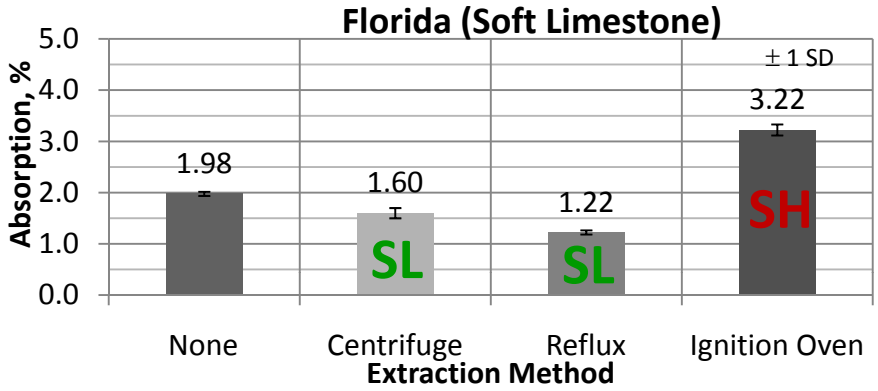


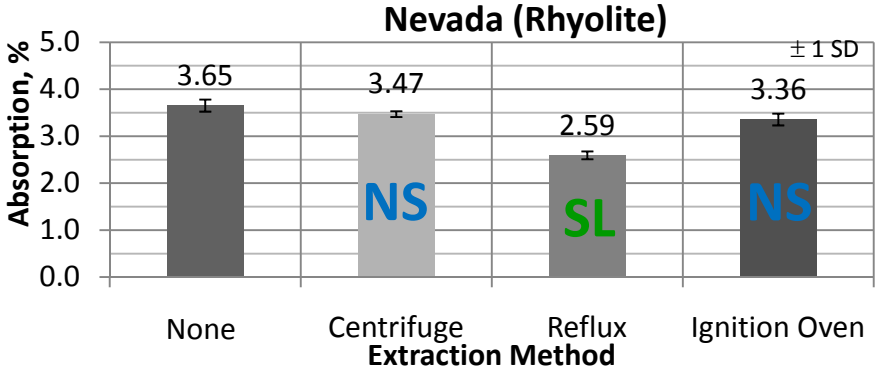


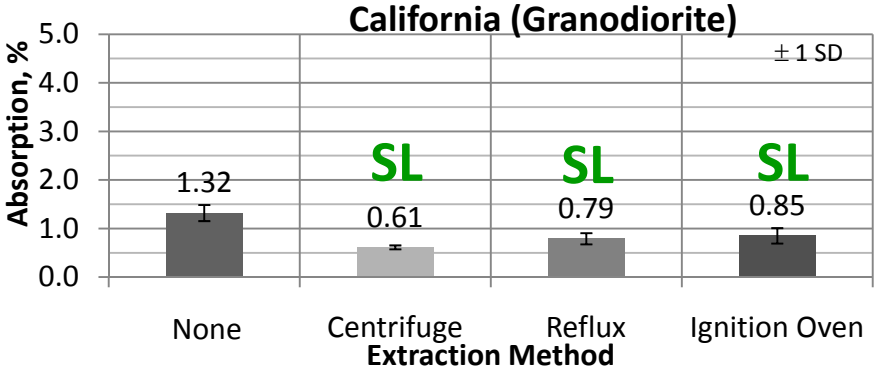


Develop a System to Evaluate the Properties of RAP
Fine Aggregate – Absorption

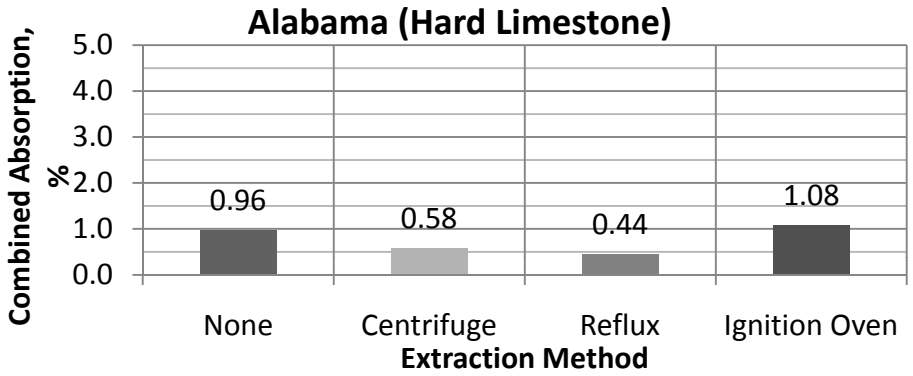


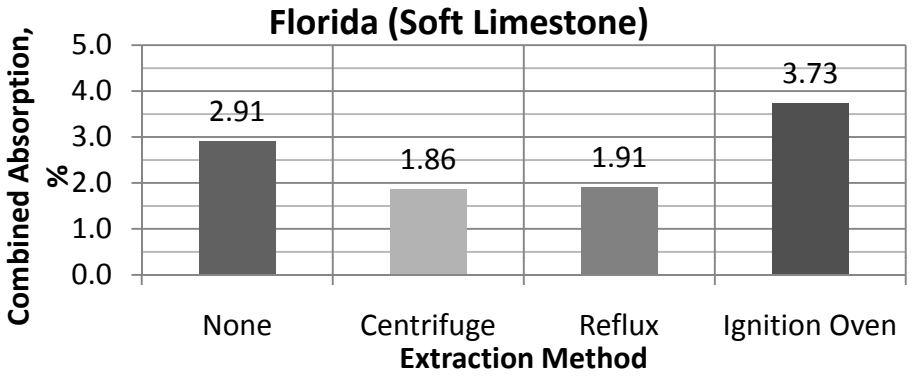


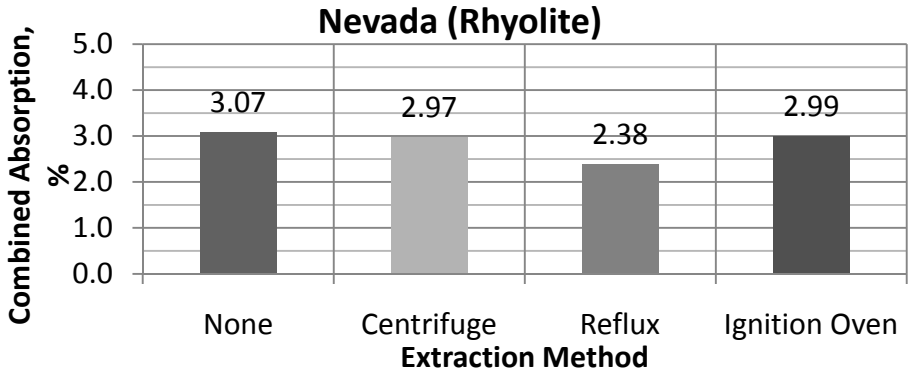


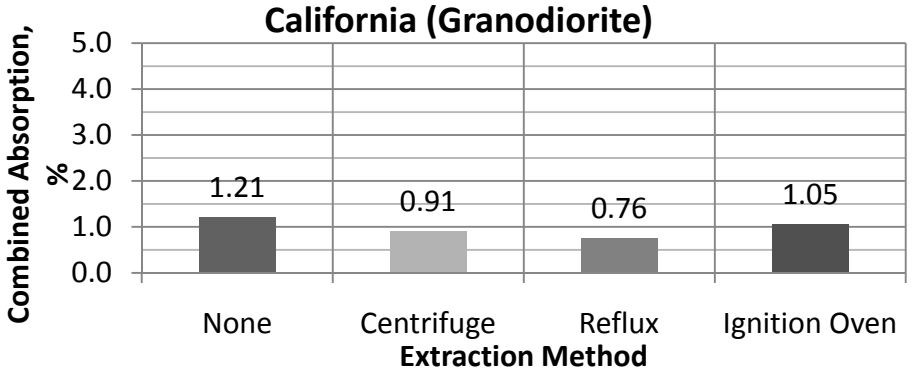


Develop a System to Evaluate the Properties of RAP
Combined Aggregate – Absorption









Develop a System to Evaluate the Properties of RAP

Summary of Paired Mean Comparisons Results for Various Aggregate Properties

Aggregate Properties	Centrifuge			Reflux			Ignition		
	SL	NS	SH	SL	NS	SH	SL	NS	SH
Sieve analysis									
- 1/2 inch sieve	--	4	--	--	4	--	--	4	--
- No. 4 sieve	--	4	--	1	2	1	--	3	1
- No. 8 sieve	1	2	1	2	1	1	1	2	1
- No. 50 sieve	1	1	2	1	2	1	--	2	2
- No. 200 sieve	1	2	1	1	2	1	2	--	2
Coarse aggregate specific gravities									
- Bulk dry specific gravity	2	1	1	--	2	2	3	1	--
- Saturated surface dry specific gravity	1	3	--	1	3	--	1	3	--
- Apparent specific gravity	1	3	--	1	3	--	1	3	--
Fine aggregate specific gravities									
- Bulk dry specific gravity	--	2	2	--	1	3	1	1	2
- Saturated surface dry specific gravity	1	2	1	--	2	2	1	--	3
- Apparent specific gravity	1	3	--	1	3	--	--	3	1
Coarse aggregate absorption	1	3	--	3	1	--	--	1	3
Fine aggregate absorption	3	1	--	4	--	--	2	1	1
Coarse aggregate durability index	--	2	2	1	2	1	1	-	3
Sand equivalent	--	2	2	--	2	2	--	2	2
LA abrasion mass loss	1	3	--	--	3	1	--	1	3
Uncompacted void content	3	--	1	3	--	1	3	--	1

Develop a System to Evaluate the Properties of RAP
Consequences of the Extraction Method on the SP Mix Design

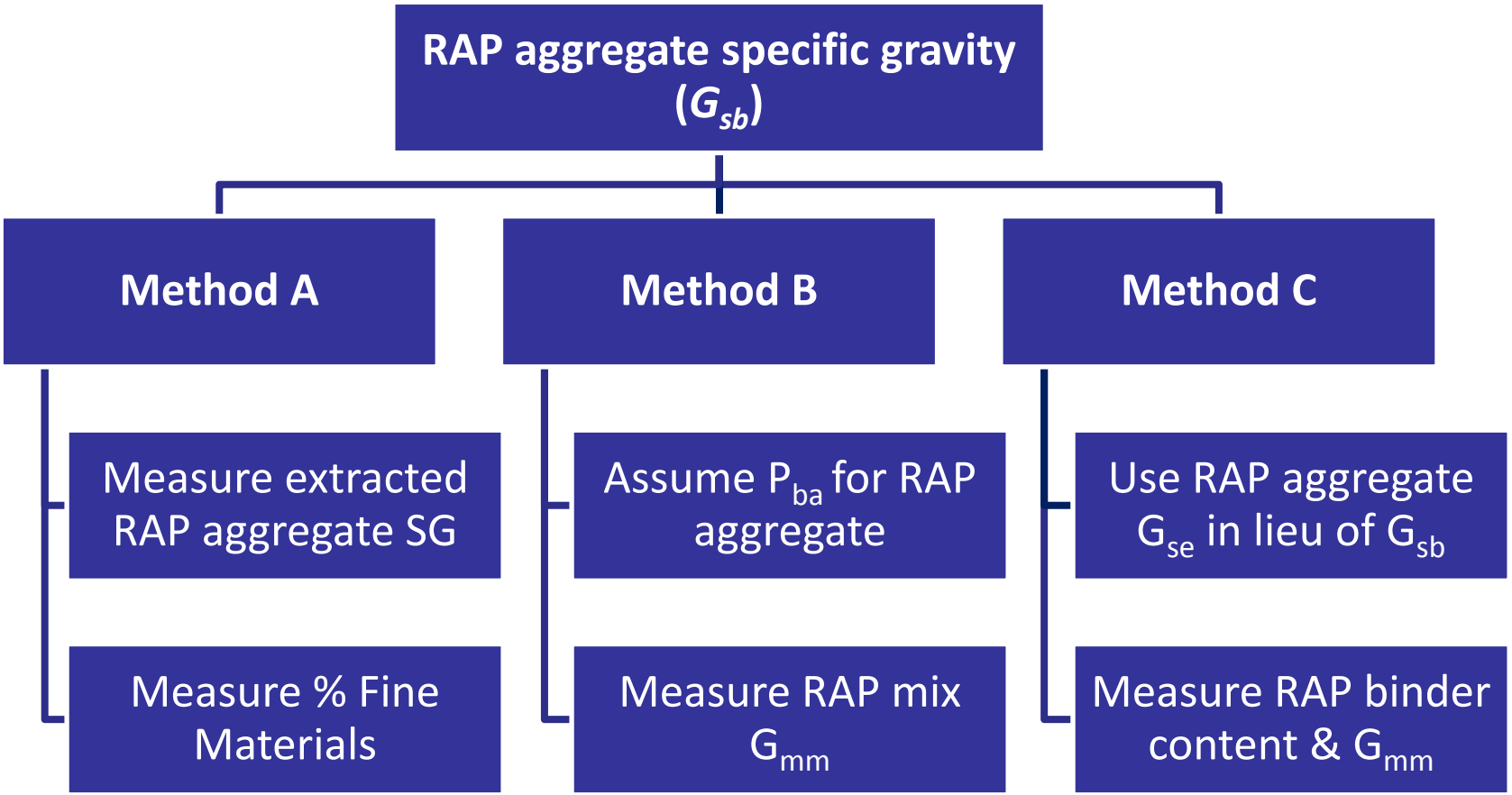
Aggregate Property	Centrifuge	Reflux	Ignition Oven
Passing #4 sieve	Close estimate 100% of time.	Close estimate 50% of time and 25% of time over- or under-estimate.	Close estimate 75% of time and 25% of time over-estimate.
Passing #200 sieve	Close estimate 50% of time and 25% of time over- or under-estimate.	Close estimate 50% of time and 25% of time over- or under-estimate.	Over-estimate 50% of time and under-estimate 50% of time.
Combined bulk dry Specific Gravity	Over-estimate 50% of time and under-estimate 50% of time. The under-estimate is likely to be caused by mixing.	Over-estimate 100% of time. The impact is masked by mixing.	Over-estimate 50% of time and under-estimate 50% of time. The under-estimate is likely to be caused by mixing.
CA fractured faces	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.
FA uncompacted voids	Over-estimate 25% of time and under-estimate 75% of time. The design will be conservative 75% of time.	Over-estimate 25% of time and under-estimate 75% of time. The design will be conservative 75% of time.	Over-estimate 25% of time and under-estimate 75% of time. The design will be conservative 75% percent of time.
FA sand equivalent	Close estimate 50% of time and over-estimate 50% of time. The design will be un-conservative 50% of time.	Close estimate 50% of time and over-estimate 50% of time. The design will be un-conservative 50% of time.	Close estimate 50% of time and over-estimate 50% of time. The design will be un-conservative 50% of time.
LA abrasion	Close estimate 75% of time and under-estimate 25% of time. The design will be un-conservative 25% of time.	Close estimate 75% of time and over-estimate 25% of time. The design will be conservative.	Close estimate 25% of time and over-estimate 75% of time. The design will be conservative.

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

- **SG of the combined gradation of RAP and virgin aggregates is required for the volumetric calculations of a mix design.**

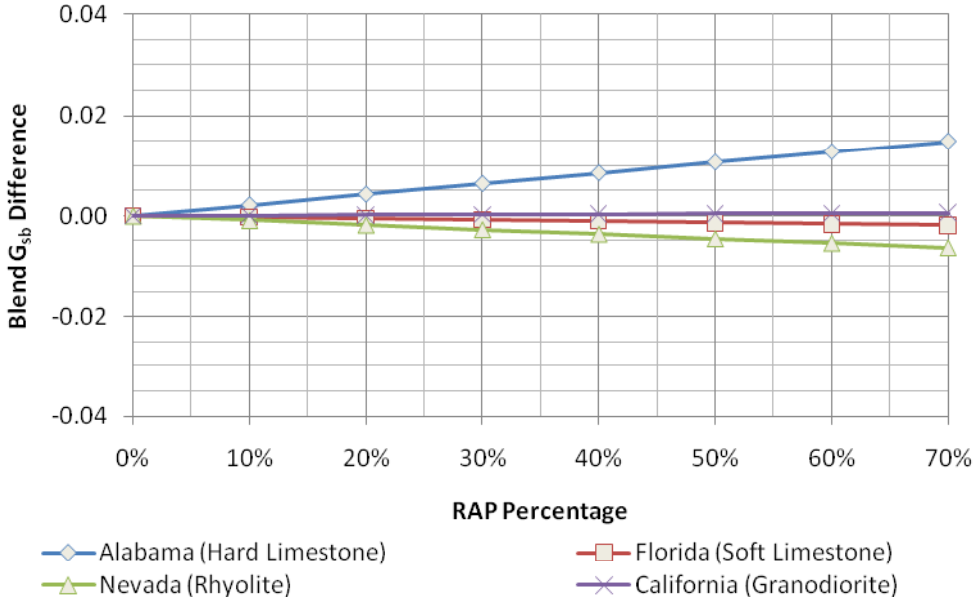
- **BSG of each aggregate stockpile, including RAP aggregate needs to be determined for the calculation of BSG of combined aggregates.**

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA



Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

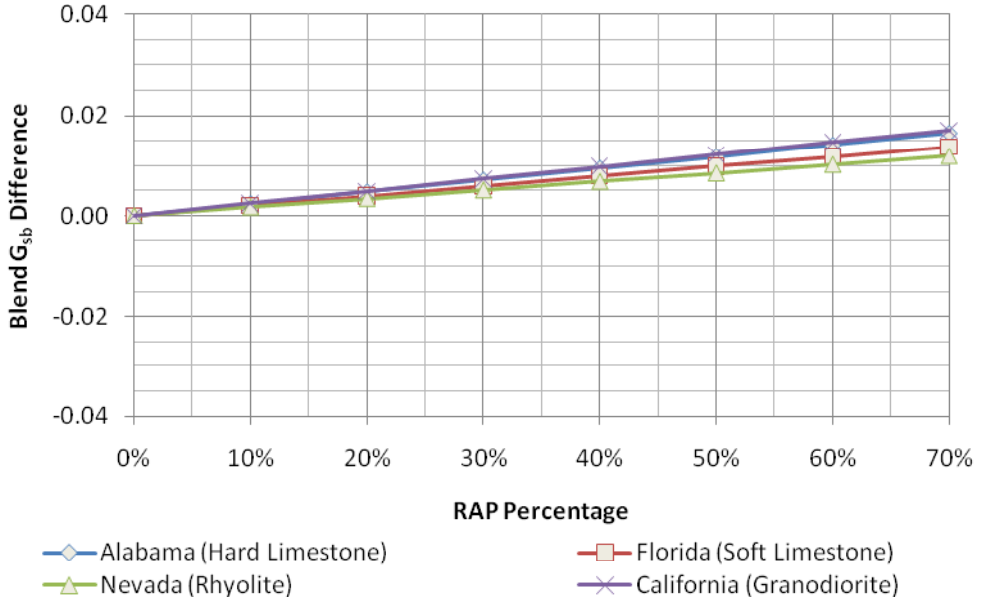
- ***Method A:*** **Difference in Blend G_{sb}**



Centrifuge

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

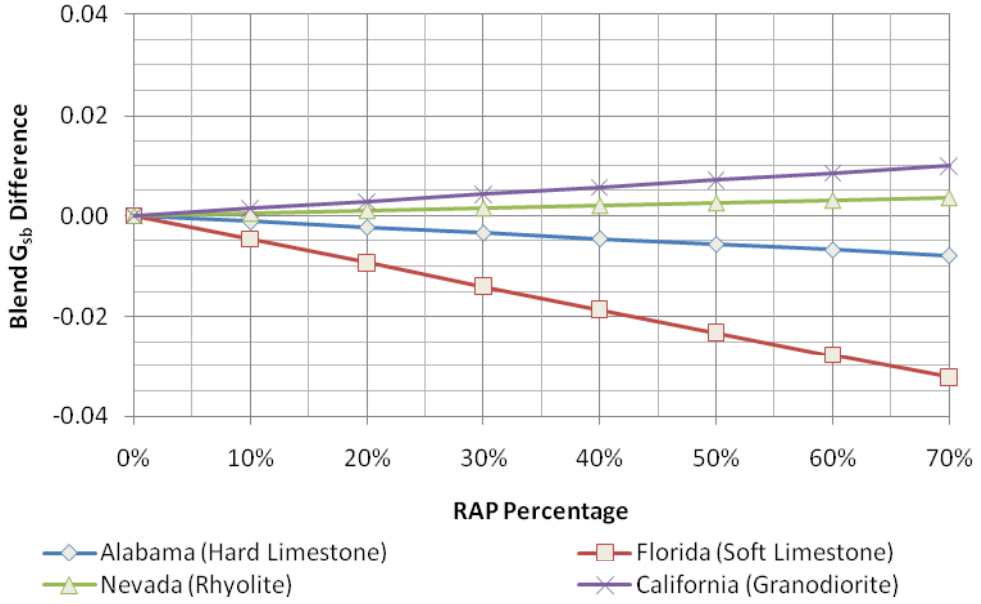
- ***Method A:*** **Difference in Blend G_{sb}**



Reflux

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

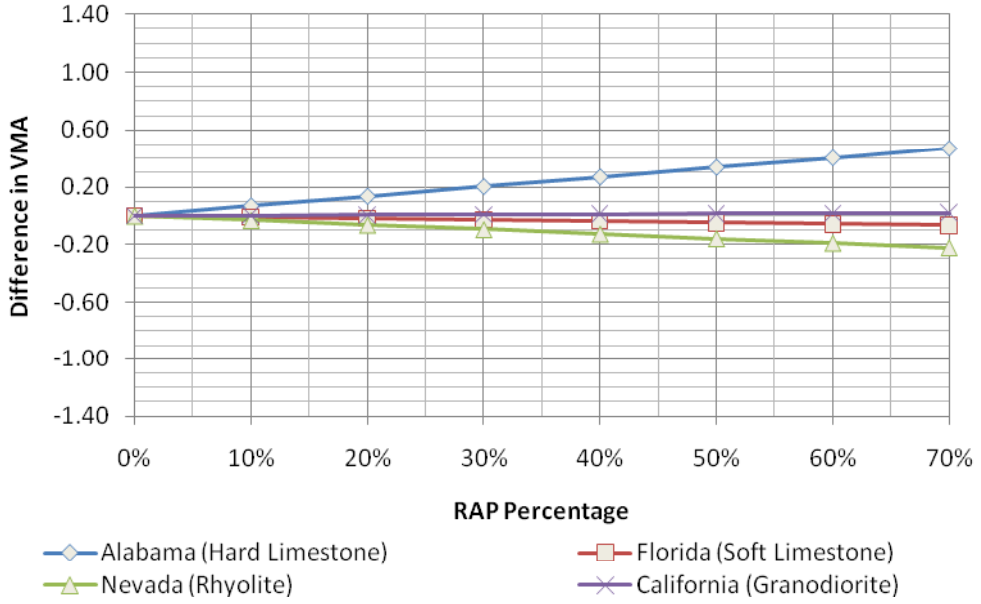
- ***Method A:*** **Difference in Blend G_{sb}**



Ignition Oven

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

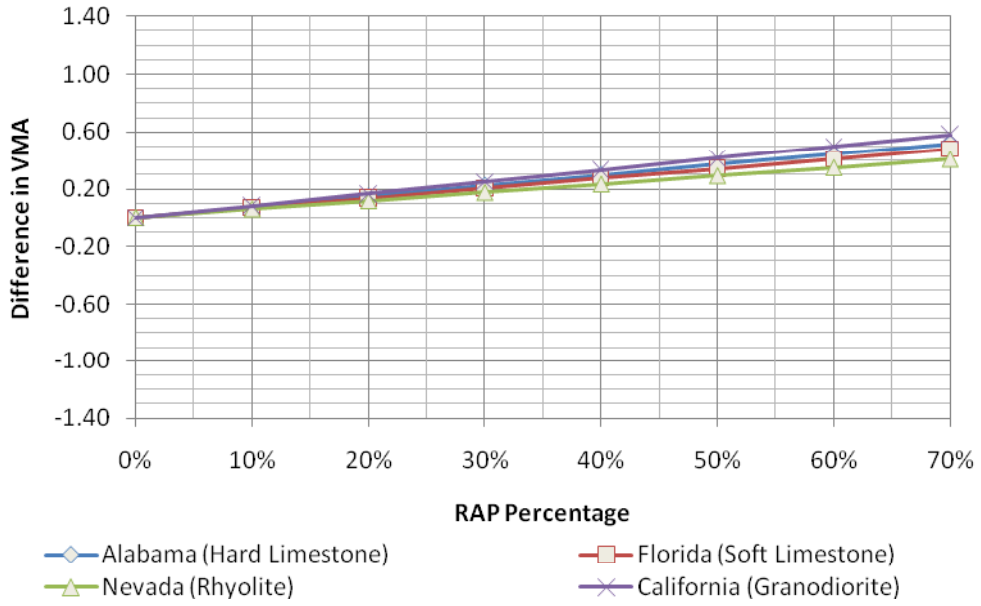
- ***Method A:*** **Difference in VMA**



Centrifuge

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

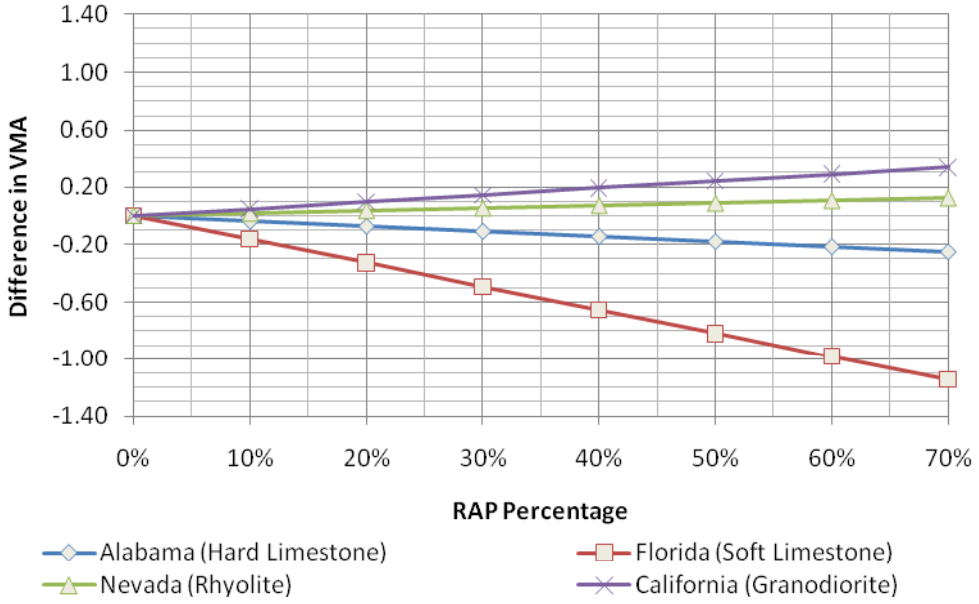
- ***Method A:*** **Difference in VMA**



Reflux

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

- ***Method A:*** **Difference in VMA**



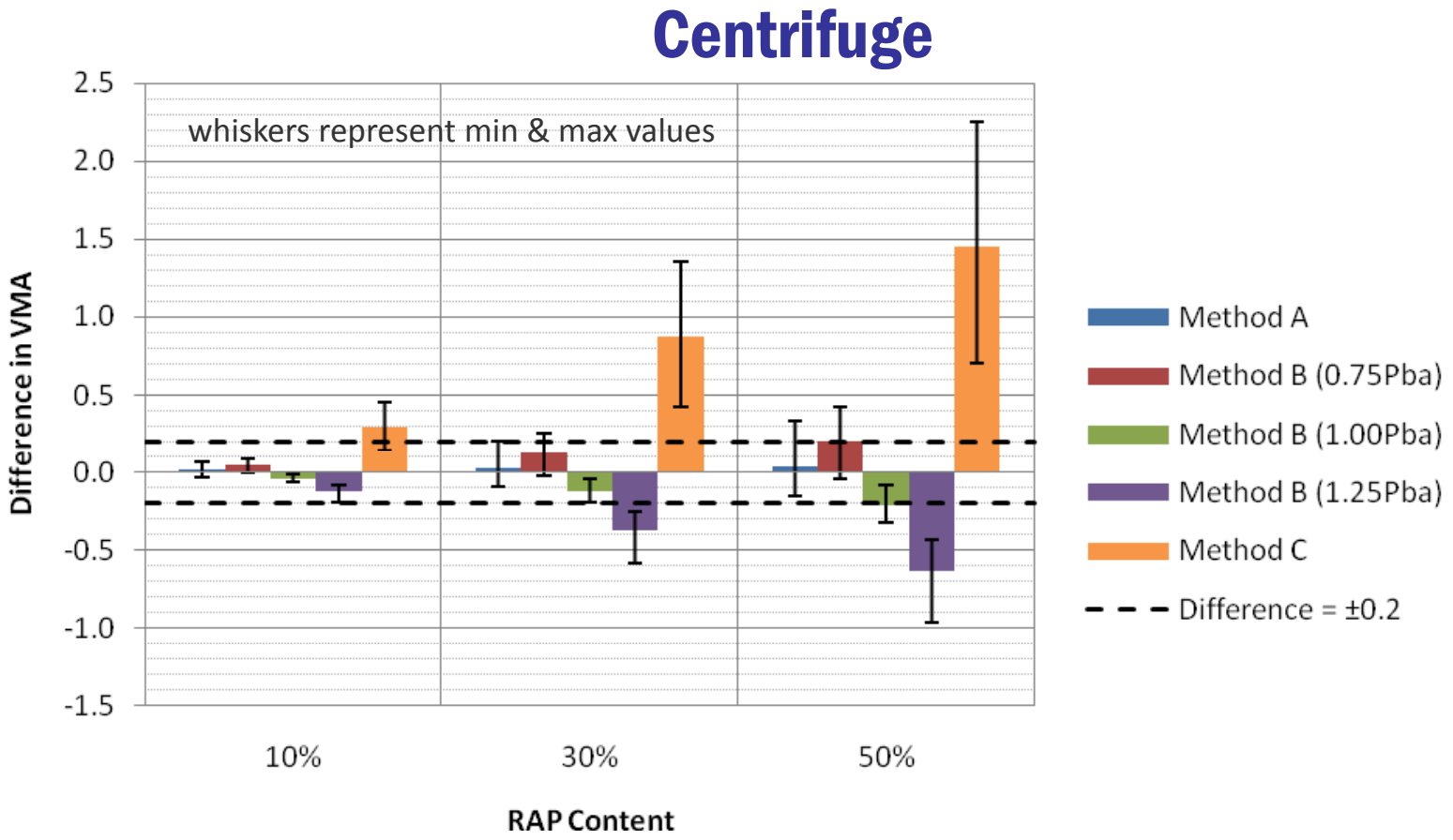
Ignition Oven

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA

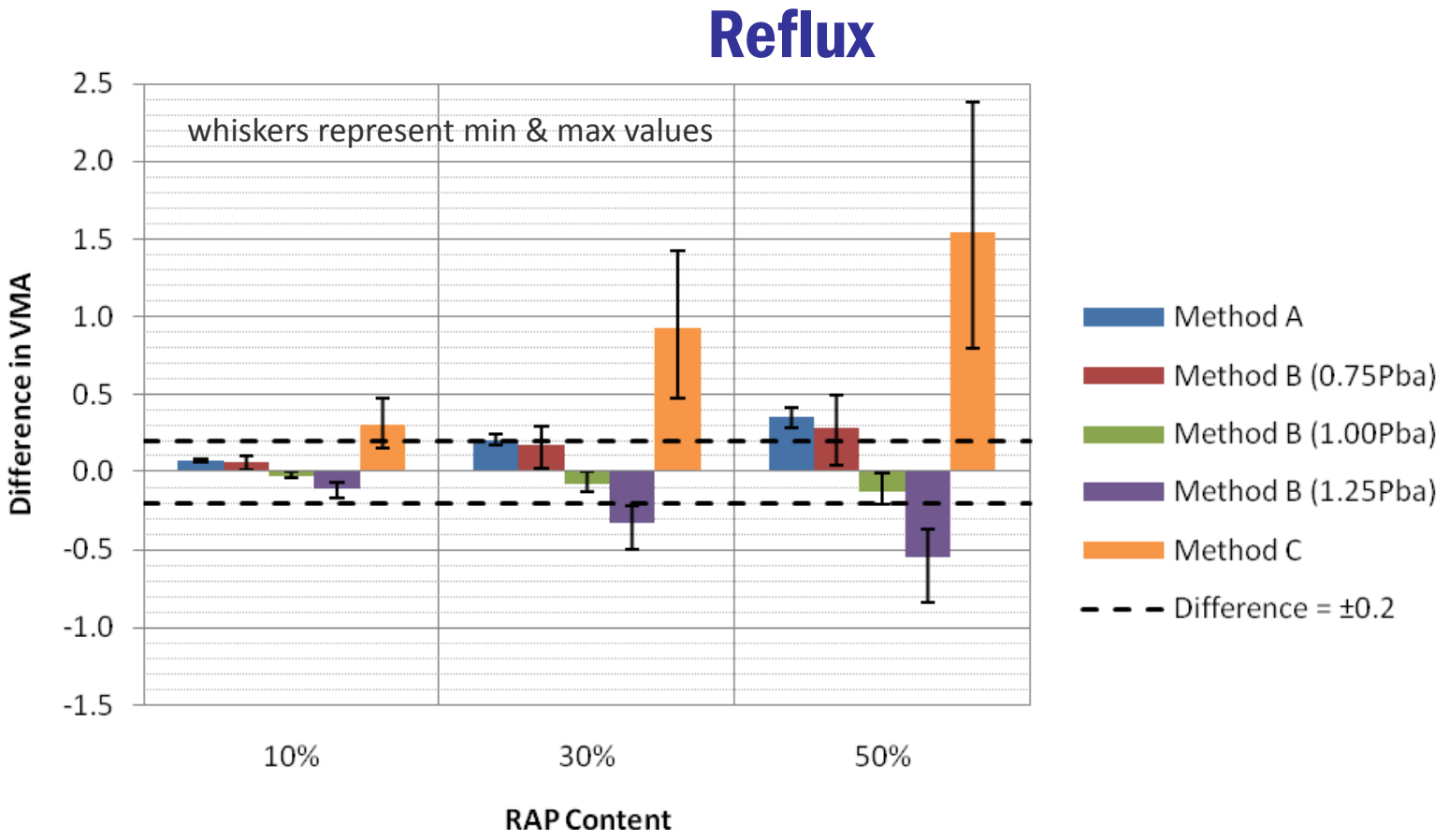
- Similar analysis and plots were developed for *Method B* and *Method C*.

- **Method B** was evaluated for three levels of assumed asphalt absorption for RAP aggregate:
  - P_{ba} (true value)
  - 75% of P_{ba} (under estimate absorption by 25%)
  - 125% of P_{ba} (over estimate absorption by 25%)

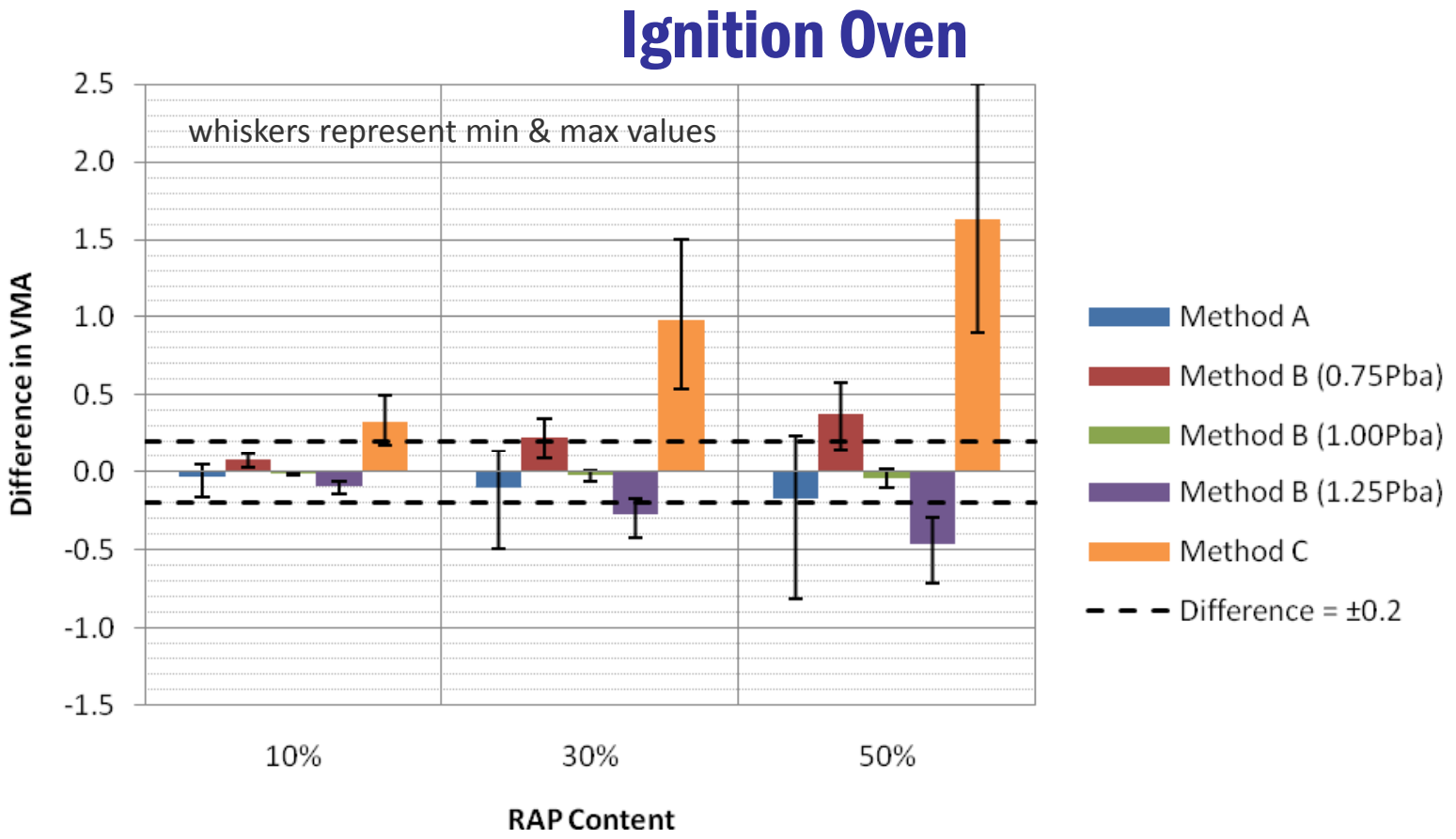
Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary



Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary



Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary



Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary

Extraction Method	RAP Content	Method A	Method B (0.75Pba)	Method B (1.00Pba)	Method B (1.25Pba)	Method C
Centrifuge	10%	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Over-estimate 50% of time. The design will be un-conservative 50% of time
	30%	Close estimate 100% of time.	Over-estimate 25% of time. The design will be un-conservative 25% of time.	Close estimate 100% of time.	Under-estimate 100% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time
	50%	Over-estimate 25% of time. The design will be un-conservative 25% of time.	Over-estimate 50% of time. The design will be un-conservative 50% of time.	Under-estimate 50% of time.	Under-estimate 100% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary

Extraction Method	RAP Content	Method A	Method B (0.75Pba)	Method B (1.00Pba)	Method B (1.25Pba)	Method C
Reflux	10%	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Over-estimate 50% of time. The design will be un-conservative 50% of time
	30%	Over-estimate 75% of time. The design will be un-conservative 75% of time.	Over-estimate 50% of time. The design will be un-conservative 50% of time.	Close estimate 100% of time.	Under-estimate 100% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time
	50%	Over-estimate 100% of time. The design will be un-conservative 100% of time.	Over-estimate 50% of time. The design will be un-conservative 50% of time.	Close estimate 100% of time.	Under-estimate 100% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time

Develop a System to Evaluate the Properties of RAP
Effect of RAP Aggregate SG on VMA – Overall Summary

Extraction Method	RAP Content	Method A	Method B (0.75Pba)	Method B (1.00Pba)	Method B (1.25Pba)	Method C
Ignition Oven	10%	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Close estimate 100% of time.	Over-estimate 75% of time. The design will be un-conservative 50% of time
	30%	Under-estimate 25% of time	Over-estimate 50% of time. The design will be un-conservative 50% of time.	Close estimate 100% of time.	Under-estimate 50% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time
	50%	Over- or under-estimate 25% of time. The design will be un-conservative 25% of time.	Over-estimate 75% of time. The design will be un-conservative 75% of time.	Close estimate 100% of time.	Under-estimate 100% of time.	Over-estimate 100% of time. The design will be un-conservative 100% of time