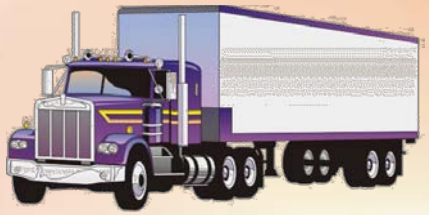
RAP RESEARCH
for
Washoe Regional Transp. Commission

Western Regional Superpave Center
University of Nevada, Reno



Objectives

- **Review current specifications for RAP Mixtures**
- **Conduct a laboratory evaluation of the impact of RAP on Mixtures performance**
- **Evaluate field produced RAP Mixtures**

Experiment

- **Three RAP sources**
  - **- plant waste**
  - **- 15-year old**
  - **- 20-year old**
- **Two binder grades**
  - **- PG64-22 (neat)**
  - **- PG64-28 (PMB)**
- **Three RAP Contents**
  - **- none**
  - **- 15 %**
  - **- 30%**

Experiment

- **Use existing technologies:**
  - **- extraction/recovery**
  - **- blending charts**
  - **- Marshall mix design**
    - **Low VMA ~ 11-12%**

Experiment

- **Performance measures:**
  - **Moisture sensitivity (T-283)**
  - **Rutting (APA)**
  - **Fatigue (Flexural Beam)**
  - **Thermal (TSRST)**

Binder Grades based on Blending Charts

RAP	RAP Binder Grade	Required Virgin Binder Grade			
		Target Binder: PG64-22		Target Binder: PG64-28NV	
		15% RAP	30% RAP	15% RAP	30% RAP
RAP Source I	PG82-16	PG64-22	PG58-28	PG64-34	PG58-34
RAP Source II	PG82-16	PG64-28	PG58-28	PG64-34	PG58-34
RAP Source III	PG82-16	PG64-28	PG58-28	PG64-34	PG58-34

PG Grades of Extracted/recovered Binders

Target Binder Grade	Mix	Critical Temperature, °C					Extracted/recovered Binder PG grade
		Original	RTFO	RTFO+PAV			
		G*/sind ≥ 1.0	G*/sind ≥ 2.2	G*sind ≤ 5000	S-value	m-value	
PG64-22	SI-22-15	N/A	74.1	27.5	-12.0	-11.8	PG70-22
	SI-22-30	N/A	75.5	27.0	-13.5	-12.5	PG70-22
	SII-22-15	N/A	75.6	24.1	-15.4	-12.3	PG70-22
	SII-22-30	N/A	71.7	23.5	-15.4	-15.2	PG70-22
	SIII-22-15	N/A	76.3	20.4	-14.0	-14.8	PG76-22
	SIII-22-30	N/A	76.6	25.0	-14.5	-12	PG76-22
PG64-28NV	SI-28-15	N/A	67.2	7.0	-29.3	-30.8	PG64-34
	SI-28-30	N/A	71.9	10.0	-25.6	-25.8	PG70-34
	SII-28-15	N/A	71.8	7.0	-27.8	-29.5	PG70-34
	SII-28-30	N/A	71.9	12.6	-24.0	-24.0	PG70-34
	SIII-28-15	N/A	74.7	7.7	-26.5	-31.5	PG70-34
	SIII-28-30	N/A	75.5	8.8	-26.5	-26.0	PG70-34

Moisture Sensitivity

Target Binder Grade	Mix	Mix Proportions	Tensile Strength, TS @ 77°F, psi				Tensile Strength Ratio, TSR (%)
			Unconditioned		Conditioned		
			average	CV* (%)	average	CV* (%)	
PG64-22	C-22	0% RAP	194	7	168	5	86
	SI-22-15	15%RAP	224	8	174	8	78
	SI-22-30	30%RAP	179	9	135	7	76
	SII-22-15	15%RAP	157	9	139	3	89
	SII-22-30	30% RAP	107	5	84	10	78
	SIII-22-15	15%RAP	180	5	160	10	89
	SIII-22-30	30% RAP	184	5	129	4	70
PG64-28NV	C-28	0% RAP	167	8	137	9	82
	SI-28-15	15%RAP	75	5	50	8	66
	SI-28-30	30%RAP	91	7	69	3	76
	SII-28-15	15%RAP	79	8	63	9	80
	SII-28-30	30% RAP	180	9	146	10	81
	SIII-28-15	15%RAP	86	10	71	6	83
	SIII-28-30	30% RAP	131	8	94	8	72

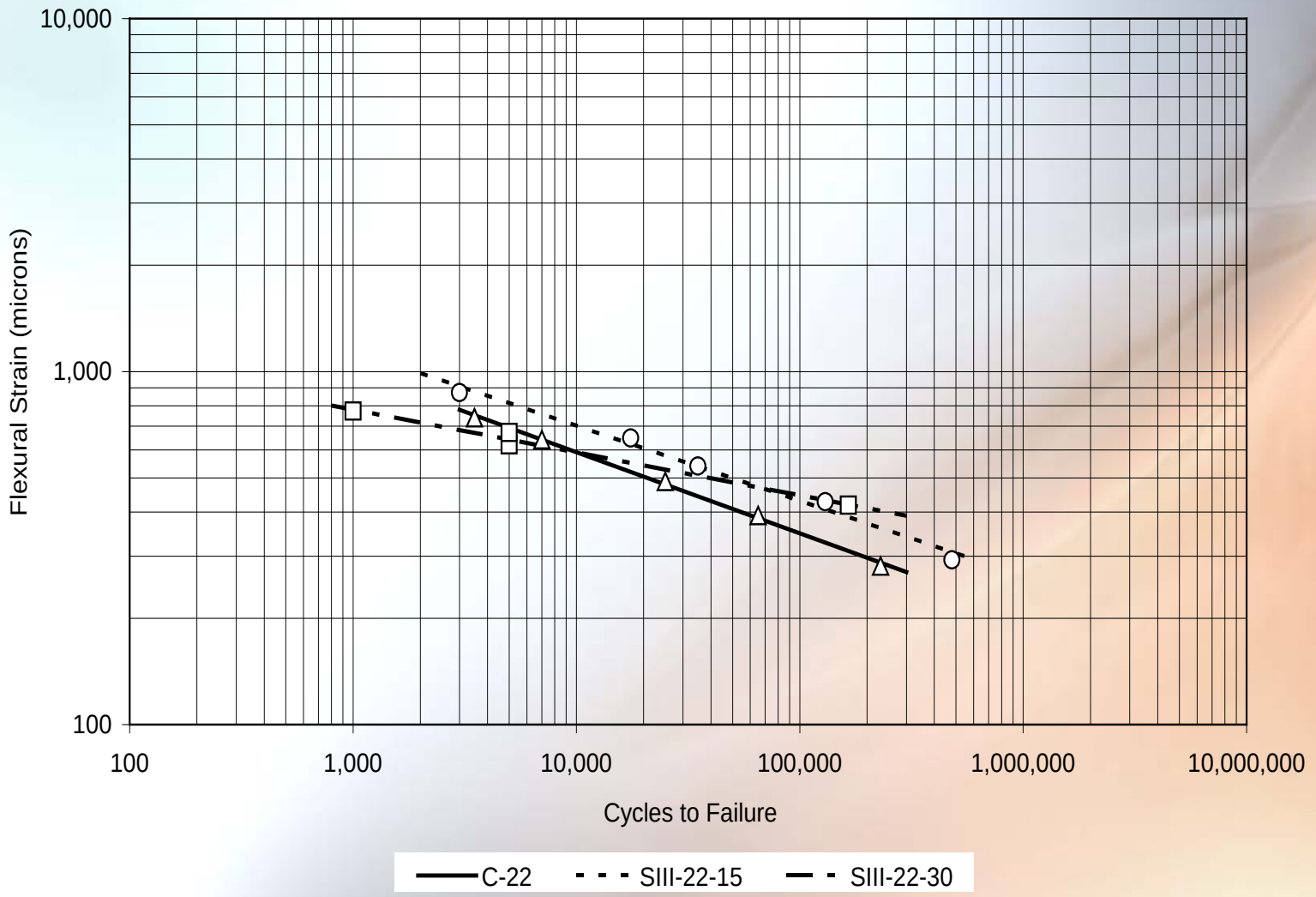
APA Rutting

Target Binder Grade	Mix	Mix Proportions	APA Rut Depth under 8,000 Cycles @ 140°F	
			mm	inch
PG64-22	C-22	0% RAP	4.6	0.18
	SI-22-15	15%RAP	5.9	0.23
	SI-22-30	30%RAP	6.0	0.24
	SII-22-15	15%RAP	2.2	0.09
	SII-22-30	30% RAP	7.3	0.29
	SIII-22-15	15%RAP	1.4	0.06
	SIII-22-30	30% RAP	2.1	0.08
PG64-28NV	C-28	0% RAP	2.1	0.08
	SI-28-15	15%RAP	2.1	0.08
	SI-28-30	30%RAP	3.1	0.12
	SII-28-15	15%RAP	2.1	0.08
	SII-28-30	30% RAP	2.4	0.09
	SIII-28-15	15%RAP	2.1	0.08
	SIII-28-30	30% RAP	2.2	0.08

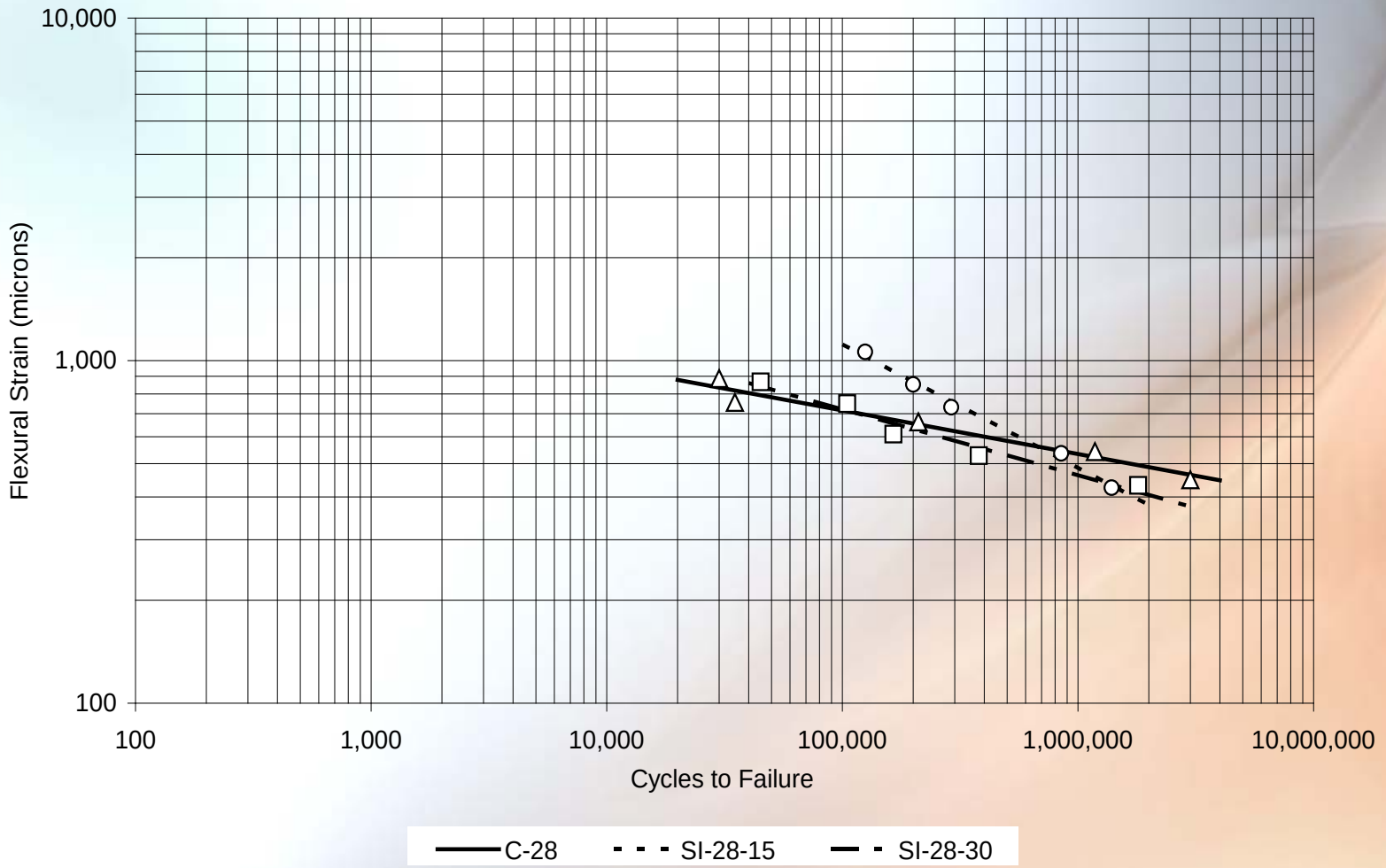
Fatigue Resistance

Target Binder Grade	Mix	Mix Proportions	Number of Cycles to Failure		
			Strain Level		
			300 microns	500 microns	700 microns
PG64-22	C-22	0% RAP	191,520	20,700	4,780
	SI-22-15	15%RAP	510,980	12,550	1,090
	SI-22-30	30%RAP	311,000	43,330	11,830
	SII-22-15	15%RAP	530,000	59,690	14,160
	SII-22-30	30% RAP	126,770	23,520	7,760
	SIII-22-15	15%RAP	546,670	49,520	10,180
	SIII-22-30	30% RAP	2,635,400	39,200	2,450
PG64-28NV	C-28	0% RAP	will not fail	1,683,400	119,850
	SI-28-15	15%RAP	3,827,100	925,600	363,400
	SI-28-30	30%RAP	9,545,000	669,000	116,180
	SII-28-15	15%RAP	will not fail	3,715,000	918,750
	SII-28-30	30% RAP	13,194,000	419,850	43,340
	SIII-28-15	15%RAP	3,621,100	773,400	279,800
	SIII-28-30	30% RAP	1,611,200	165,925	37,120

Fatigue Comparison - Neat



Fatigue Comparison - PMA



Mechanistic Analysis

Target binder grade	Mix	Resilient modulus at 77°F (ksi)	Tensile strain at the bottom of HMA layer, 4"depth, (microns)	Number of repetitions to fatigue failure, N_f	Ratio of fatigue life
PG64-22	C-22	1,091	264	337,000	--
	SI-22-15	1,086	264	1,280,000	3.80
	SI-22-30	392	458	61,000	0.18
	SII-22-15	730	333	338,000	1.01
	SII-22-30	340	488	25,500	0.08
	SIII-22-15	873	301	537,000	1.60
	SIII-22-30	672	349	757,000	2.25
PG64-28NV	C-28	668	350	27,600,000	--
	SI-28-15	211	587	592,000	0.02
	SI-28-30	296	517	556,000	0.02
	SII-28-15	279	530	2,920,000	0.11
	SII-28-30	849	306	11,570,000	0.42
	SIII-28-15	249	554	567,000	0.02
	SIII-28-30	516	401	444,400	0.02

Thermal Cracking - TSRST

Target Binder Grade	Mix	Mix Proportions	Fracture Temperature (°C)
PG64-22	C-22	0% RAP	-18
	SI-22-15	15%RAP	-17
	SI-22-30	30%RAP	-26
	SII-22-15	15%RAP	-29
	SII-22-30	30% RAP	-22
	SIII-22-15	15%RAP	-16
	SIII-22-30	30% RAP	-23
PG64-28NV	C-28	0% RAP	-24
	SI-28-15	15%RAP	-39
	SI-28-30	30%RAP	-35
	SII-28-15	15%RAP	-40
	SII-28-30	30% RAP	-40
	SIII-28-15	15%RAP	-39
	SIII-28-30	30% RAP	-28

Conclusions

- **Moisture Sensitivity is OK**
- **Rutting is OK**
- **Fatigue: Depends on content and PG**
  - **30% is worse**
  - **adding RAP to PMA is worse**
- **Thermal Cracking is OK**

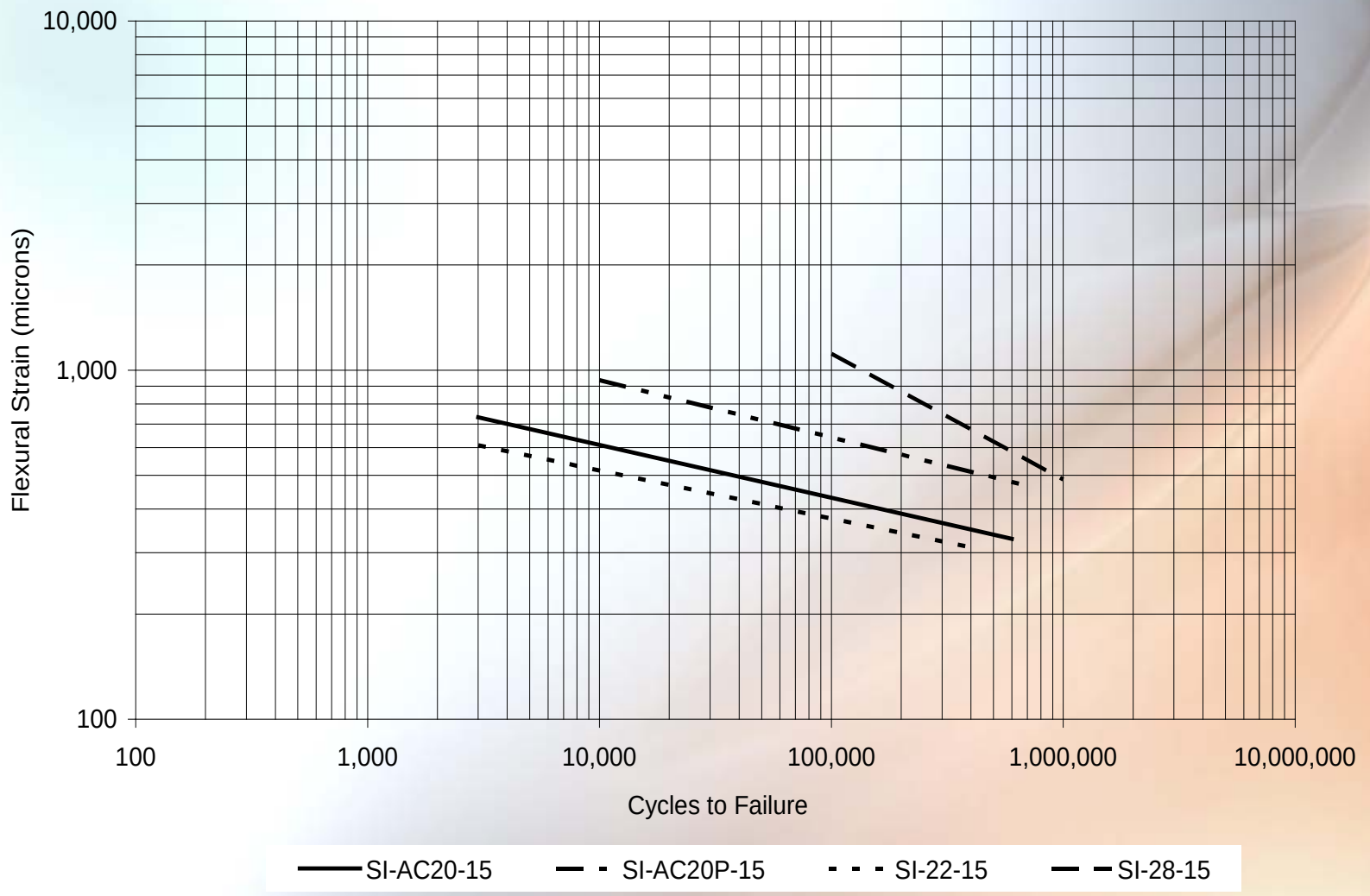
Field Produced Mix

- Plant waste RAP at 15%
- No Change of grade of virgin binder
- AC-20 and AC-20P Mixtures
- Moisture Sensitivity
  - AC-20 passed min TS but failed TSR
  - AC20P passed both
- Rutting
  - AC-20P significantly better resistance than AC-20

Extracted/Recovered Binder Plant Waste – 15%

Aging	Performance Criteria	Test Method	Property	PG Specification	Critical Temperature, °C	
					SI-AC20-15	SI-AC20P-15
Original	Rutting	DSR+	G*/sinδ	≥ 1.0 kPa	NA	NA
RTFO	Rutting	DSR	G*/sinδ	≥ 2.2 kPa	72.4	70.6
RTFO +PAV	Fatigue	DSR	G*sinδ	≤ 5000 kPa	25.2	17.9
	Thermal Crack	BBR#	S-value	≤ 300 MPa	-15.0	-20.3
			m-value	≥ 0.3	-13.1	-17.1
Superpave Performance Asphalt Binder Grade					PG70-22	PG70-22

Fatigue of Field Mixtures



Thermal Cracking

Mix	RAP Percentage	Asphalt Binder	Fracture Temperature (°C)
SI-AC20-15	15%	AC-20 (PG64-22)	-21
SI-AC20P-15	15%	AC-20P (PG64-28NV)	-29

Proposed Consortium Activities

- ***Team: UNR, Granite, UWM, WRI, AAT***
- ***Task 1: Develop a System to Evaluate the Properties of RAP Materials***
- ***Task 2: Compatibility of RAP and Virgin Binders***
- ***Task 3: Develop a Mix Design Procedure***

Proposed Consortium Activities

- ***Task 4: Impact of RAP Materials on Performance of Mixtures***

- ***Task 5: Field Trials***