Performance of Asphalt Mixes Containing Post-Consumer Recycled (PCR) Plastics: Balanced Mix Design (BMD) Approach

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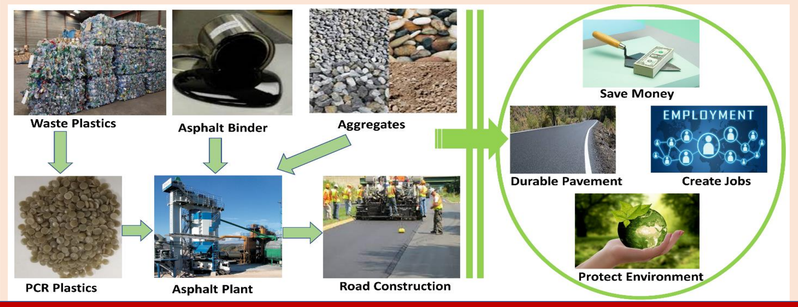
TRB ANNUAL MEETING

INTRODUCTION

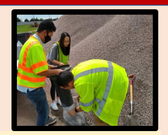
- **37.5M tons** of waste plastic in 2018 in the U.S. ; **less than 9% recycled**
- Using recycled plastics improves asphalt pavement performance and opens **new market**
- Recycling of plastic accounted for **28,000 jobs. $1.3B in wages; and $1.68B in revenue**
- Annually **2M tons** of plastic can be used in pavement, **7% of landfill disposal**
- Use of **Post-Consumer Recycled (PCR)** plastics poses several challenges**, mixing protocol, volumetric and performances**
- Properties of plastic-modified mixes need to evaluated using **Balanced Mix Design (BMD)** criteria; **Rutting and Cracking**



OBJECTIVES

- To identify a suitable mixing protocol for incorporating waste plastic using dry process
- To evaluate the effect of plastic on volumetrics properties of a surface mix
- To evaluate the performances of plastic-modified asphalt mixes with respect to BMD
- To evaluate the effect of long-term aging on the performances of plastic-modified asphalt mixes

MATERIALS & METHODS

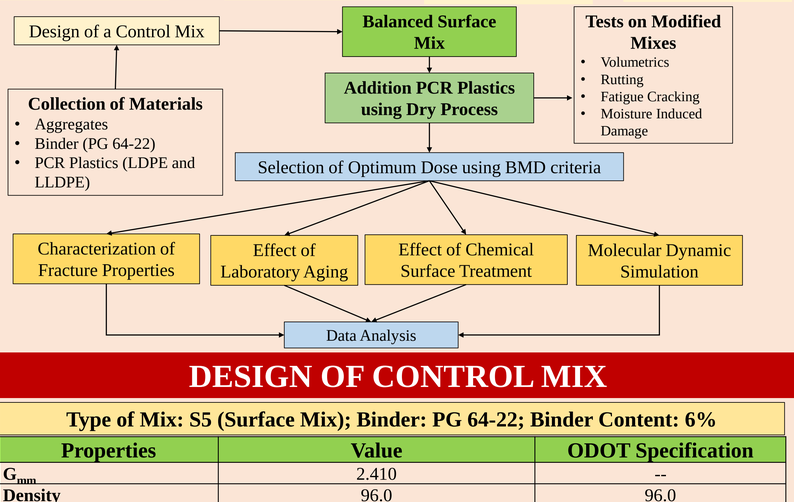


Aggregate Collection

Asphalt Binder

LDPE

LLDPE



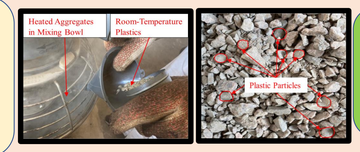
DESIGN OF CONTROL MIX

Type of Mix: S5 (Surface Mix); Binder: PG 64-22; Binder Content: 6%

Properties	Value	ODOT Specification
G_{mm}	2.410	--
Density	96.0	96.0
VMA	15.5	15.5/15.0
VFA	74.2	73.0-78.0
Permeability (cm/s)	2.0 X 10^{-5}	≤12.5 X 10^{-5}
TSR	0.94	≥0.80
Rut (mm)	4.10	≤12.5
CT_{Index}	145	≥80

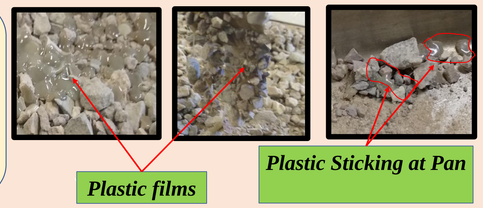
PLASTIC MIXING PROTOCOL

Approach-1
Heated Aggregate +Cold Plastic → Aggregate-Plastic Mixture + Binder = Asphalt Mix



- **Temperature loss**
- **No coating**

Approach-2
Aggregate +Plastic → Hot Aggregate-Plastic Mixture + Hot Binder = Asphalt Mix



Plastic films

Plastic Sticking at Pan

Approach-3
Room-Temperature Plastic Added During Mixing = Asphalt Mix

- ***No paper like film***
- ***No sticking on pan***

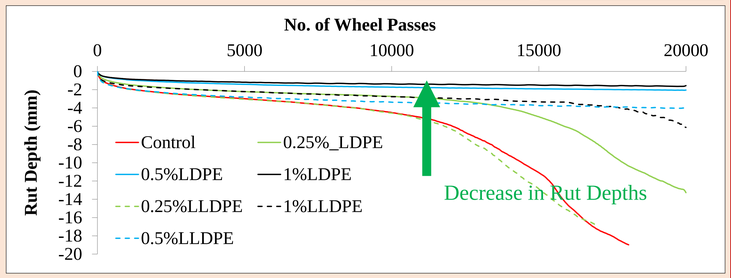
Approach-3 was finally selected

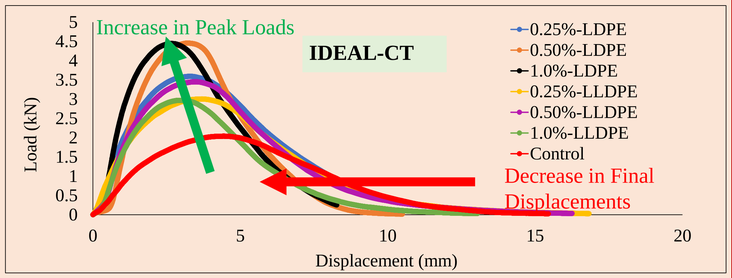
EFFECT ON VOLUMETRIC PROPERTIES

ID	Gmm	Gmb	%Density	Air Voids (%)
Control	2.410	2.313	96.0	4.0
0.25-LDPE	2.394	2.306	96.3	3.7
0.5-LDPE	2.391	2.304	96.4	3.6
1.0-LDPE	2.375	2.293	96.5	3.5
0.25-LLDPE	2.391	2.308	96.5	3.5
0.5-LLDPE	2.375	2.305	97.1	2.9
1.0-LLDPE	2.361	2.299	97.4	2.6

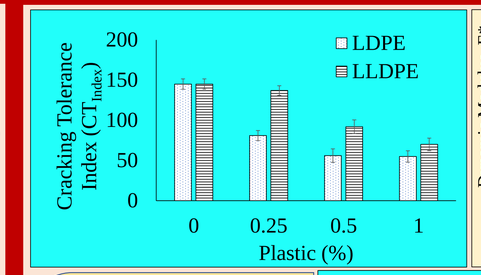
- Low specific gravities of plastics caused reduction in G_{mm} and G_{mb}.
- Higher reduction in G_{mm} as compared to G_{mb} resulted in higher densities.

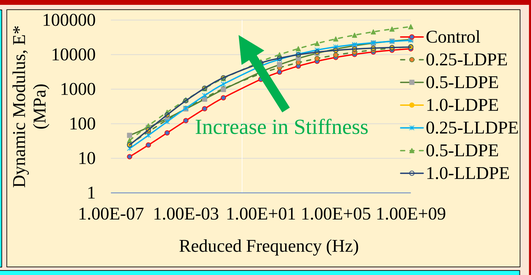
EFFECT ON PERFORMANCES



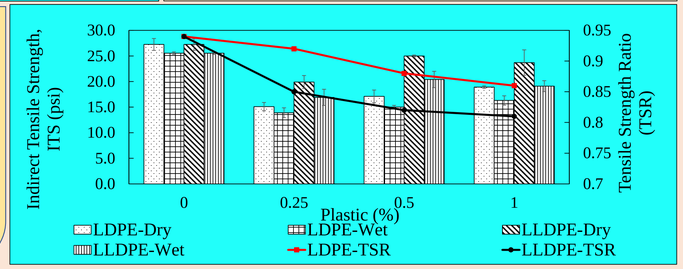


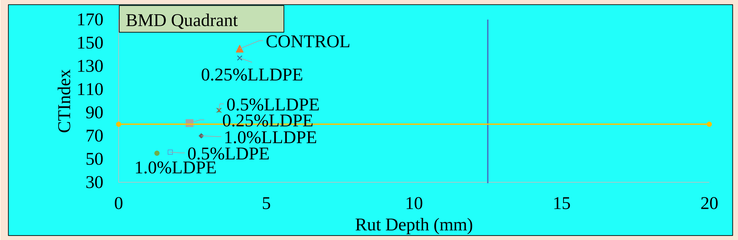
EFFECT ON PERFORMANCES





- Increase in rutting resistance and decrease in cracking resistance due to stiffness contributed by plastic particles
- Reduction in moisture resistance
- LLDPE is more prone to moisture induced damage





- 0.25%-LDPE, 0.25%-LLDPE and 0.5%-LLDPE-modified mixes satisfied BMD criteria

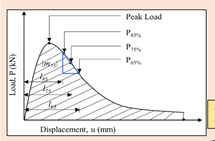
FUTURE STEPS

Aging Study → Binder Extraction and Recovery → Unaged / Short-Term Aged / Long-Term Aged → Tests on Extracted Binder

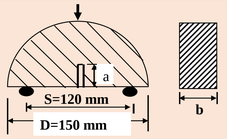
Rheological Analysis
- Rotational Viscosity (RV) Test
- Dynamic Shear Rheometer (DSR) Test

Chemical Analysis
- SARA Fraction Analysis
- Fourier Transform Infrared Spectroscopy (FTIR) Test

Data Analysis
- Effect on Performance Grade (PG)
- Aging Indices
- Effect on Chemical Functional Groups



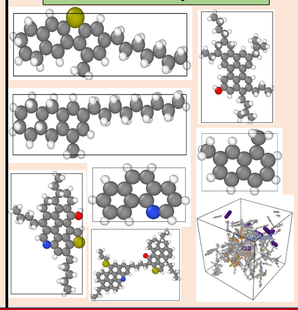
Fracture Study → Control Mix → Plastic Modified Mix



Illinois Flexibility Index Test (IFIT) | Louisiana Semi-Circular Bend (L-SCB) Test | Indirect Tensile Asphalt Cracking Test (IDEAL-CT)

→ **Data Analysis**

Interaction between Plastics and Asphalt Mix Components → Molecular Dynamic (MD) Simulation → Preparation of Virgin Asphalt Model → Calculation of Density and Viscosity → **MD Simulation of Plastic-Modified Mix** → **Data Analysis**



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