66TH ILLINOIS BITUMINOUS PAVING CONFERENCE

Mix Design Optimization and Artificial Intelligence

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Outline

- Background
- Motivation
- Data Preparation
- Model Analysis
- ICT Mix Design Tool
- Conclusion

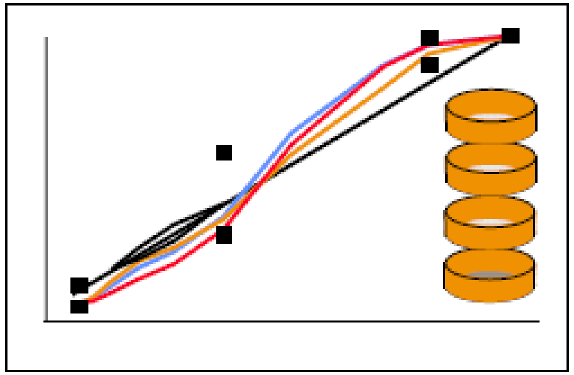
Introduction

- **Goal of asphalt mix design is to produce well performing mix for a given pavement application**
- **Resistant to**
  - cracking,
  - rutting, and
  - Moisture
- **Also have a workable mix**
  - Produced according to design and
  - reach target density in field

Components of Asphalt Mixture Design

- **Determine mix type and number of gyrations**
  - E.g IL-9.5 N50
- **Select materials**
  - Grade of asphalt binder
  - Type and gradations of aggregates

- **Design aggregate structure**
- **Batch trial blend**
  - Compact to Ndes and prepare Gmms



- **Run volumetrics**
- **Optimum binder content**
- **Run performance tests**

Motivation

- **Reduce time to design mixes:** AI-driven first-trial saves time and cost
- **Smart optimization:** Uses machine learning and genetic algorithms to improve accuracy
- **Flexible and adaptable**
  - Supports predictions using user-defined aggregates and long-term aging (LTA)

Data Preparation

Database Size

I-FIT: 18,677 datasets from **2,061** mixes (LTA: **253**)

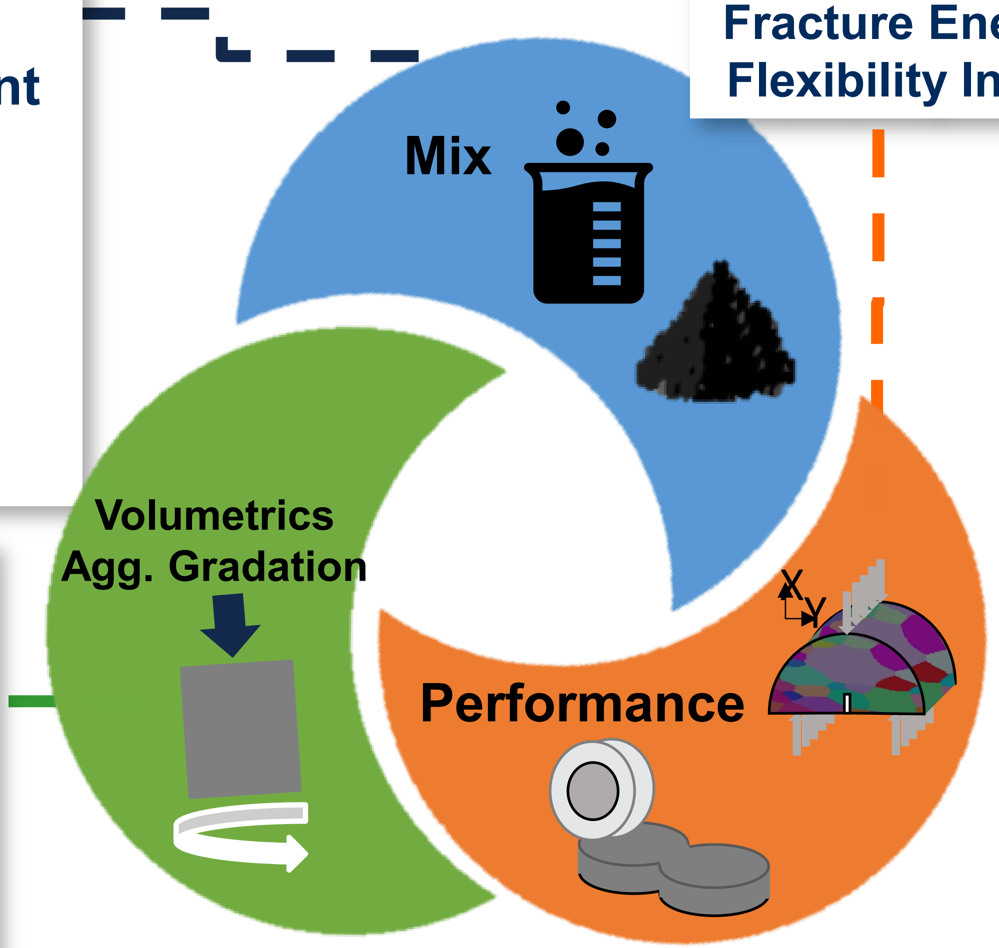
HWTT: 8,263 datasets from **3,782** mixes

I-FIT & HWTT: 5,365 datasets from **1,956** mixes

Gyrations
Agg. Gradation
Binder PG
Binder Content
Polymer
RAP/RAS
ABR
SC/BC/LB
NMAS
AC/SMA

Rut Depth
No. of Passes
Fracture Energy
Flexibility Index

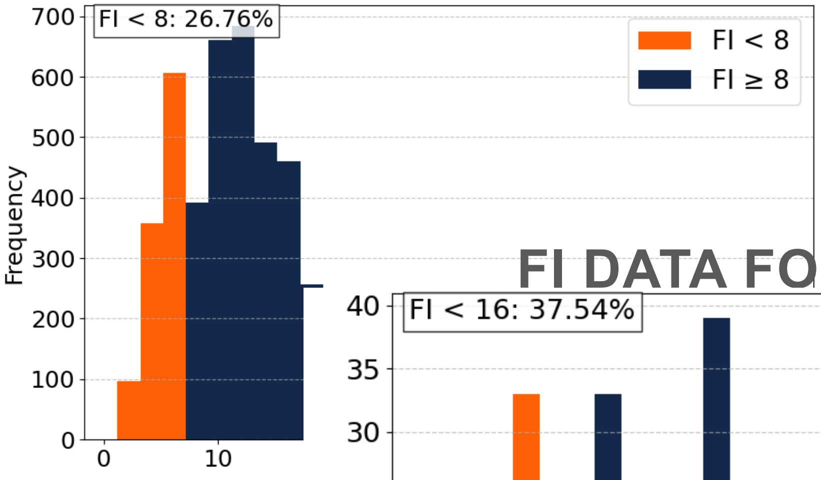
Gradation
G_{mb}
G_{mm}
G_{sb}
AV
VMA
V_{be}



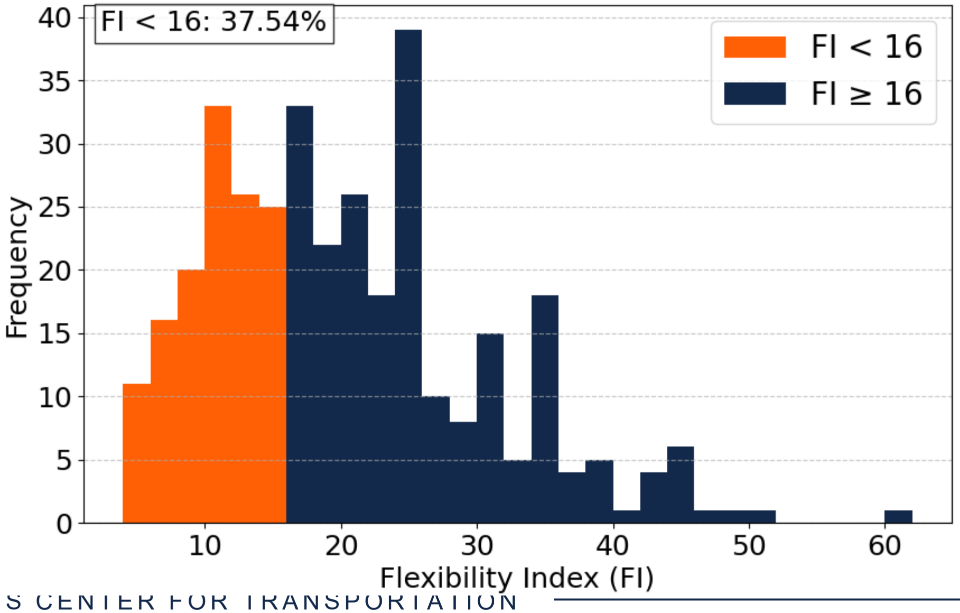
Database Breakdown

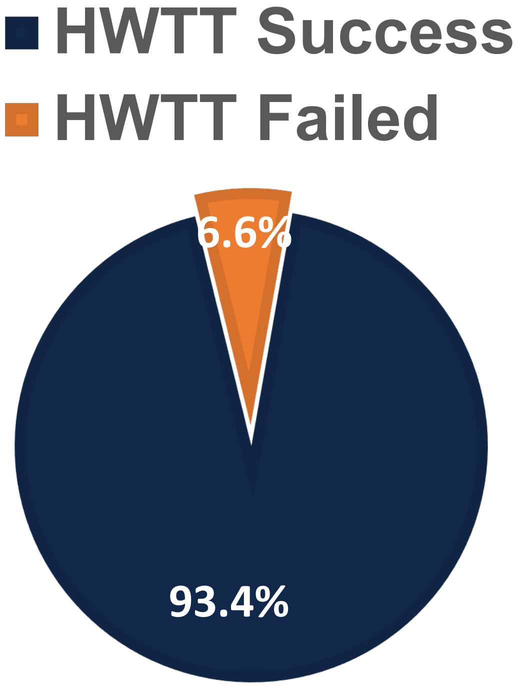
- **I-FIT:** 18,677 samples (9,133 design, 8,947 plant, 597 cores)
- **HWTT:** 8,260 samples (8,235 gyratory compacted, 24 cores)

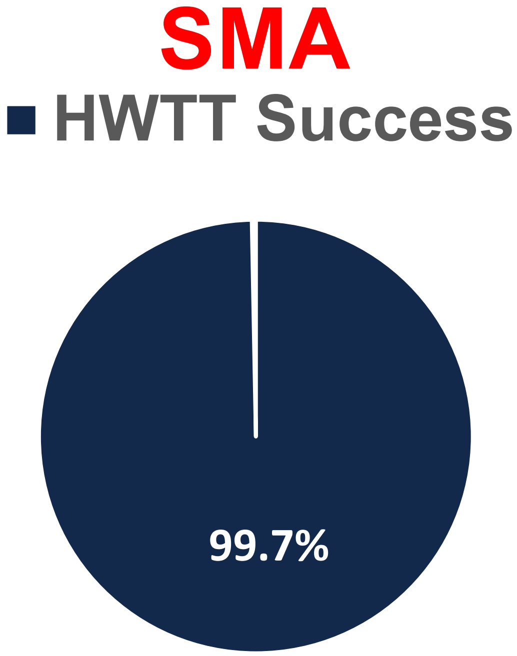
FI DATA FOR HMA STA



FI DATA FOR SMA STA

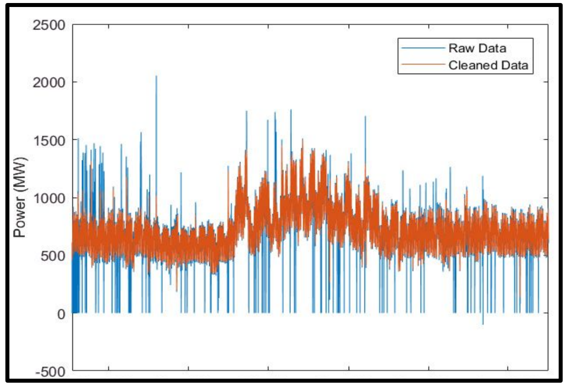




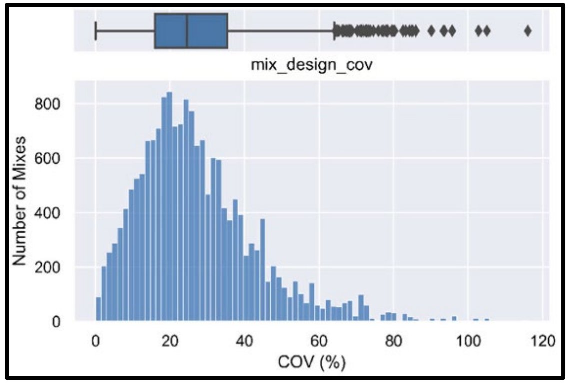


Data Preprocessing

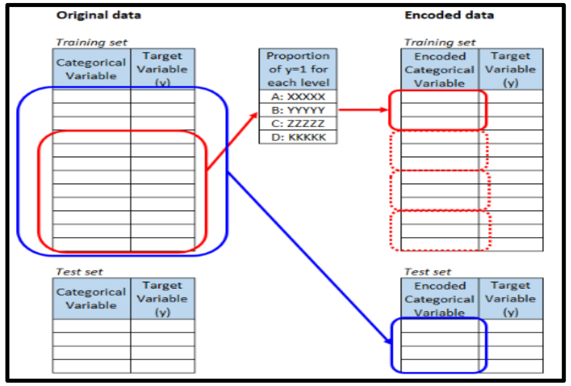
DATA COMPILATION AND CLEANING



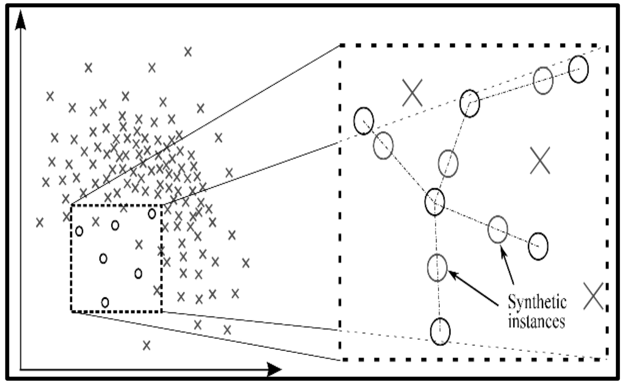
COV CHECK FOR I-FIT FI AND HWTT RD



DATA TRANSFORM AND CATEGORICAL

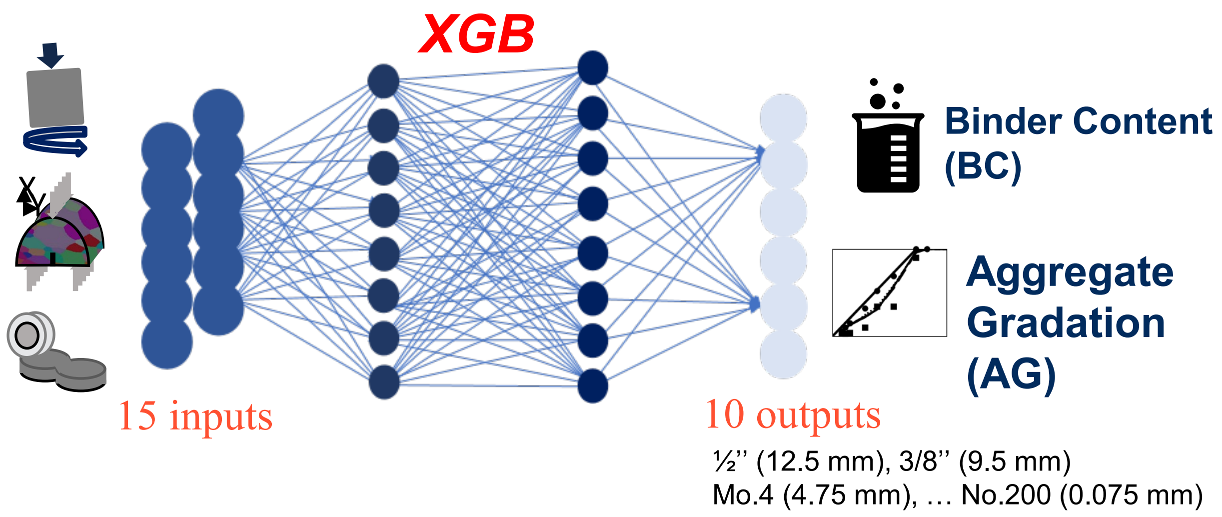


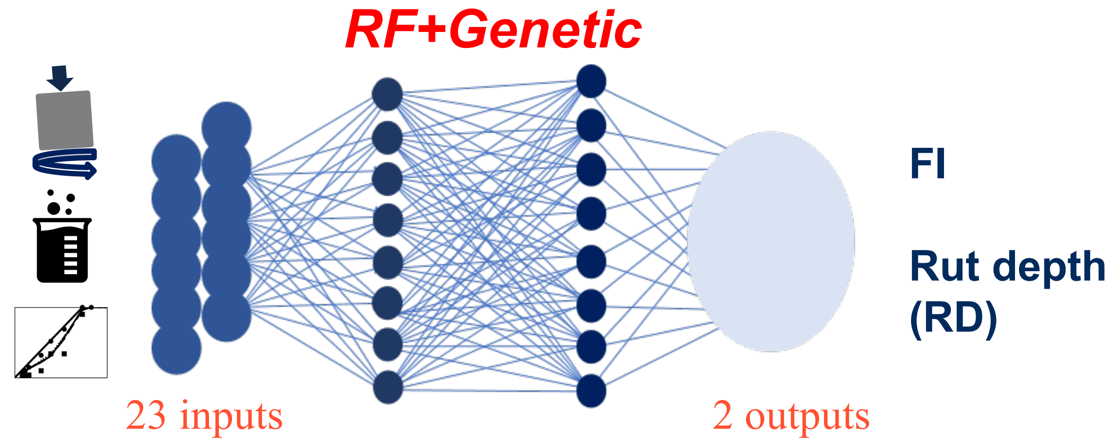
DATA OVERSAMPLING TECHNIQUE



Two-step ML Model

- **Step 1**: Predict preliminary aggregate gradation and AC content for desired FI and RD using a multioutput regressor.
- **Step 2**: Fine-tune VMA, RAP, AC content, and aggregate gradation from Step 1 to meet target performance using a genetic algorithm.





Model Analysis and Results

- **Step 1**: XGB model accurately predicted AC content and aggregate gradation (R^2 = 0.96 with and w/o LTA).

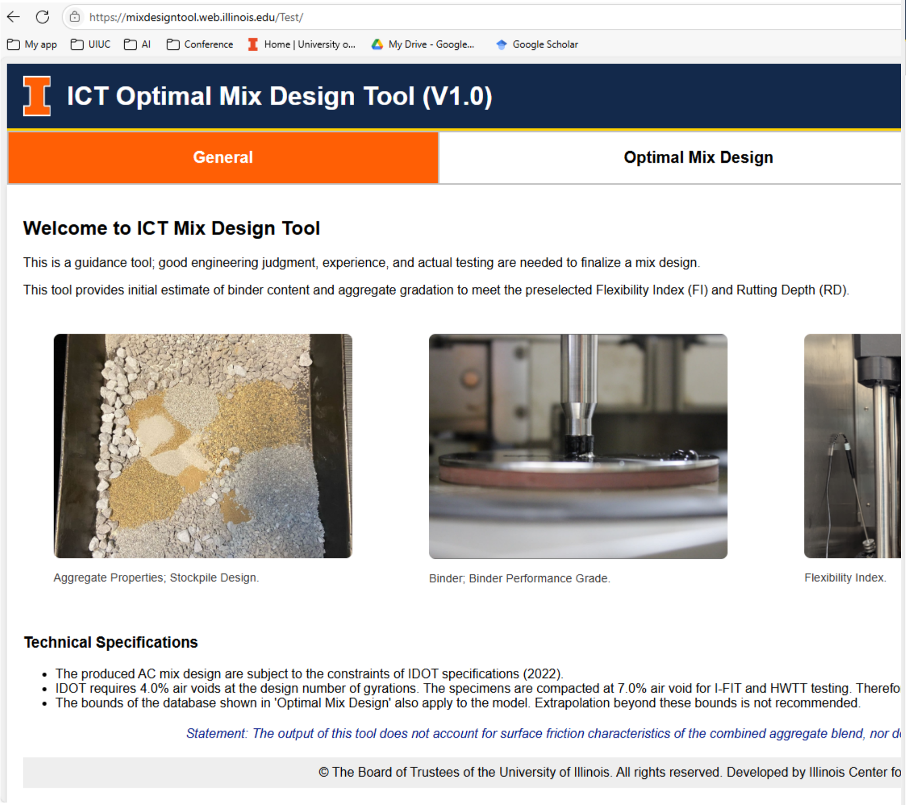
Targets	Metrics	SVR	DNN	XGB
Overall Performance	R^2	0.634	0.876	0.956
	MSE	13.8	0.775	0.717
	MAE	2.017	2.101	0.321

- **Step 2**: RF model, using a genetic algorithm, optimized AC mixture design to meet specified FI and RD requirements.

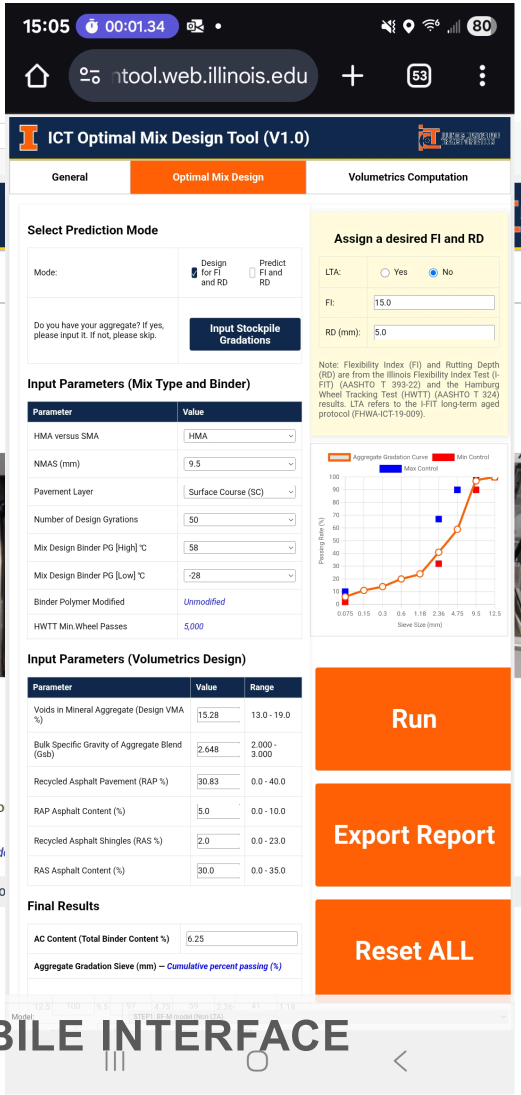
Model	DNN	RF
I-FIT FI - R^2	0.747	0.80
HWTT RD - R^2	0.797	0.789

Web-based ICT Optimal Mix Design Tool

[HTTPS://MIXDESIGNTOOL.WEB.ILLINOIS.EDU/TEST/](https://mixdesigntool.web.illinois.edu/Test/)



DESKTOP INTERFACE



MOBILE INTERFACE

🌐 **Accessible via** phone, tablet, and web.

⏱️ **Fast predictions:** Each run takes less than a minute.

🔄 **Supports two-way predictions:**

- Predict Design for FI & RD
- Predict FI & RD for a Design

📁 **Allows users to input their own aggregate data** for custom optimization.

Case Study – SMA STA

NMAS 9.5; GYRATIONS 80

Select Prediction Mode

Mode:	☑ Design for FI and RD	☐ Predict FI and RD
Do you have your aggregate? If yes, please input it. If not, please skip.	Input Stockpile Gradations	

Input Parameters (Mix Type and Binder)

Parameter	Value
HMA versus SMA	SMA
NMAS (mm)	9.5
Pavement Layer	Surface Course (SC)
Number of Design Gyrations	80
Mix Design Binder PG [High] °C	76
Mix Design Binder PG [Low] °C	-28
Binder Polymer Modified	*Modified*
HWTT Min.Wheel Passes	*20,000*

Input Parameters (Volumetrics Design)

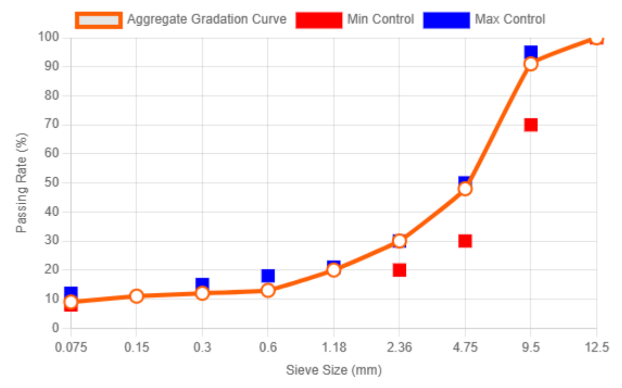
Model: STEP1: RF-M model (Non-LTA)

Parameter	Value	Range

Assign a desired FI and RD

LTA:	○ Yes ◉ No
FI:	19.1
RD (mm):	5.0

Note: Flexibility Index (FI) and Rutting Depth (RD) are from the Illinois Flexibility Index Test (I-FIT) (AASHTO T 393-22) and the Hamburg Wheel Tracking Test (HWTT) (AASHTO T 324) results. LTA refers to the I-FIT long-term aged protocol (FHWA-ICT-19-009).



- RAP: 30%
- RAS: 0
- Opt.Pb: 6.5%
- Pred.Pb: 6.37%
- Pred.Pb is 0.13% lower
- Pred.FI: 19.1
- Pred.RD: 5.5

Case Study #2 – HMA STA

NMAS 9.5; GYRATIONS 70

Select Prediction Mode

Mode:	☑ Design for FI and RD	☐ Predict FI and RD
Do you have your aggregate? If yes, please input it. If not, please skip.	Input Stockpile Gradations	

Input Parameters (Mix Type and Binder)

Parameter	Value
HMA versus SMA	HMA
NMAS (mm)	9.5
Pavement Layer	Surface Course (SC)
Number of Design Gyrations	70
Mix Design Binder PG [High] °C	64
Mix Design Binder PG [Low] °C	-22
Binder Polymer Modified	*Unmodified*
HWTT Min.Wheel Passes	*7,500*

Input Parameters (Volumetrics Design)

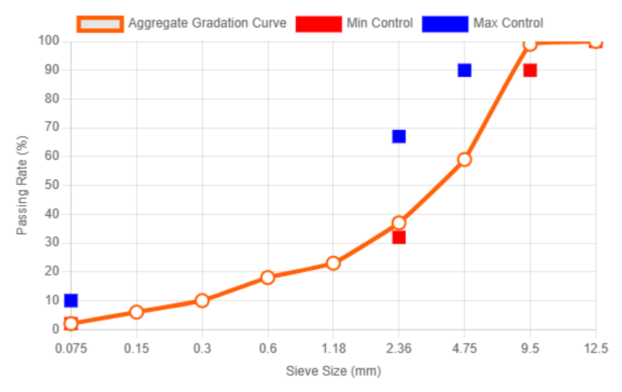
Model: STEP1: RF-M model (Non-LTA)

Parameter	Value	Range

Assign a desired FI and RD

LTA:	○ Yes ◉ No
FI:	15.0
RD (mm):	8.0

Note: Flexibility Index (FI) and Rutting Depth (RD) are from the Illinois Flexibility Index Test (I-FIT) (AASHTO T 393-22) and the Hamburg Wheel Tracking Test (HWTT) (AASHTO T 324) results. LTA refers to the I-FIT long-term aged protocol (FHWA-ICT-19-009).



- RAP: 0%
- RAS: 0
- Opt.Pb: 5.5%
- Pred.Pb: 5.78%
- Pred.Pb is 0.28% higher
- Pred.FI: 15.0
- Pred.RD: 7.7

Summary and Future Work

- **Two-step approach, first predicting AC content and aggregate gradation, then fine tuning to improve mix design accuracy**
- **AI-driven framework and web-based tool improve asphalt mix design efficiency by:**
  - Saving time and cost,
  - Providing a reliable, performance-based optimization approach
  - Supporting user-defined materials

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THANK YOU

Any Questions?

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