



Asphalt Mixture Automated Testing System with Zero Intervention (AMAZE): Revised Training Curriculum

Product 0-6674-03-P4

Cooperative Research Program

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**ASPHALT MIXTURE AUTOMATED TESTING SYSTEM WITH ZERO
INTERVENTION (AMAZE):**

REVISED TRAINING CURRICULUM

by

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DISCLAIMER

This research was sponsored by the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Fujie Zhou.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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TABLE OF CONTENTS

	Page
List of Figures.....	vi
Section I. Introduction.....	1
Section II. Instructor Guide—Course Module.....	3
Section III. Student Participant Guide	21
Space Requirements.....	21
Electrical Requirements	21
System Description	22
Radio-Frequency Identification (RFID) Unit	22
Carousel Unit	24
Air Voids Unit.....	24
Specimen Conditioning Units	26
Specimen Storage Unit	27
Loading Frame Unit.....	28
Robot Arm Unit	28
Central Computer Unit.....	29
Seven Testing Options	30
Pre-Testing Preparation	30
Testing Operation Procedure	37
Post-Testing Operation	40
Section IV. Training Presentation	41

LIST OF FIGURES

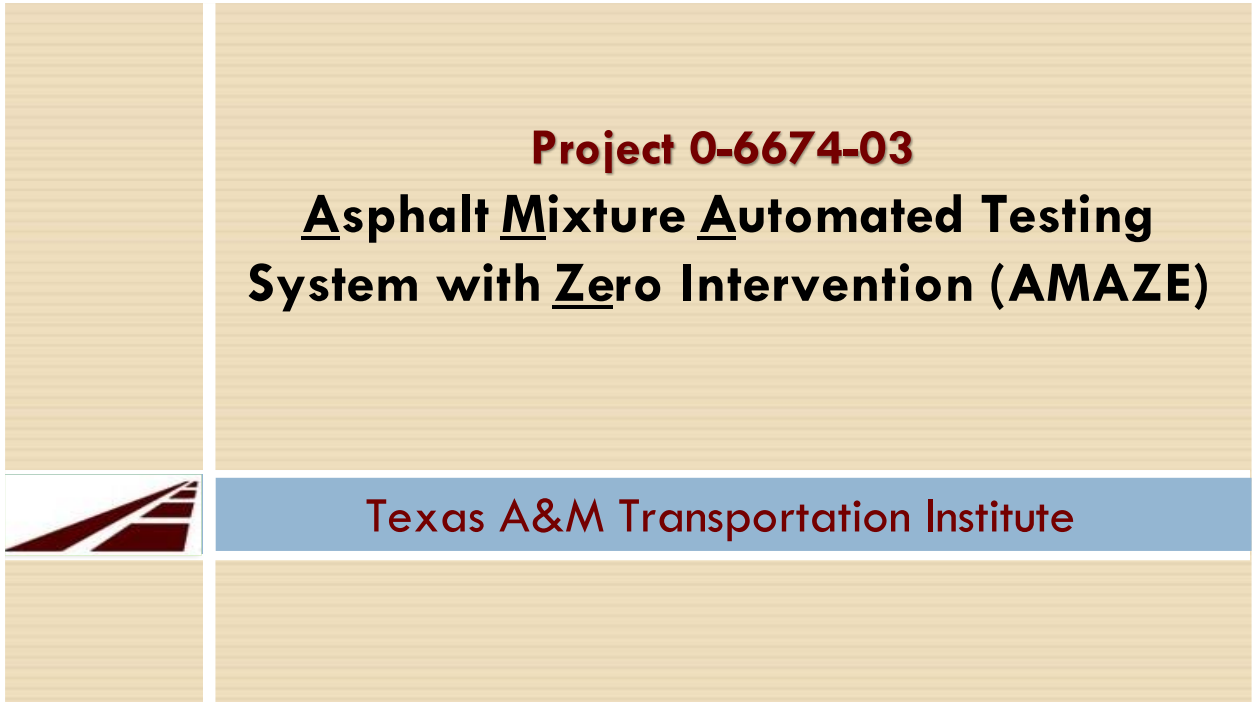
	Page
Figure 1. Top View of System.....	21
Figure 2. Desktop RFID Staging Unit	23
Figure 3. Sample RFID Reader.....	23
Figure 4. Carousel Unit.....	24
Figure 5. Weight Measurement Component.....	25
Figure 6. Saturated Surface Dry Component.....	25
Figure 7. Specimen Conditioning Unit for IDEAL-CT (or IDEAL-RT).....	26
Figure 8. Specimen Storage Unit.....	27
Figure 9. Loading Frame Unit	28
Figure 10. Robot Arm	29
Figure 11. Central Computer Unit	29
Figure 12. RFID Tag on Asphalt Specimen.....	31
Figure 13. AMAZE Registrar Software.....	32
Figure 14. Robot Arm Power Button.....	33
Figure 15. Starting Robot Initiation	33
Figure 16. Turning On Robot.....	34
Figure 17. Starting Robot.....	34
Figure 18. Exit Button and Run Tab.....	35
Figure 19. Play Button	35
Figure 20. Robot Program Playing	36
Figure 21. Stop Button.....	36
Figure 22. AMAZE Icon.....	37
Figure 23. AMAZE System Control Screen	37
Figure 24. Importing Test Profile	38
Figure 25. Screen for Assigning a Test Name	38
Figure 26. Screen of Machine Status	39
Figure 27. Presentation of Test Results	40

SECTION I. INTRODUCTION


State highway agencies including the Texas Department of Transportation (TxDOT) are currently facing many challenges. Three such challenges involve addressing (a) the cracking and rutting distresses that are costing taxpayers billions of dollars annually, (b) the loss of both the workforce and the skills associated with the workforce, and (c) laboratory safety concerns to prevent worker injury. TxDOT is addressing the cracking and rutting problems by implementing a balanced mix design method to design durable mixes. However, the lack of workforce and workforce skills hinders such efforts to some extent. Additionally, the primary safety concern in the laboratory has always been preventing worker injury often associated with the hot asphalt, large masonry saws, high-force testing machines, and toxic chemicals typically found in an asphalt material testing laboratory. Automation of certain processes can alleviate all these safety concerns by reducing the number of employees exposed to the different hazards. An innovative solution to addressing these three current issues is to develop an asphalt mixture automated testing system with zero intervention (AMAZE), which was the goal of Project 0-6674-03.

As one of the deliverables of Project 0-6674-03, this training curriculum includes an instructor guide, a participant guide, and a presentation.

SECTION II. INSTRUCTOR GUIDE—COURSE MODULE



Project 0-6674-03
**Asphalt Mixture Automated Testing
System with Zero Intervention (AMAZE)**



Texas A&M Transportation Institute

Key Message	Training title
Interactive	In this training session, we will present the <u>A</u> sphalt <u>M</u> ixture <u>A</u> utomated Testing System with <u>Z</u> ero Intervention (AMAZE).
Notes	N/A

Presentation outline



- Introduction
 - Motivation
 - Objective
- AMAZE development
- AMAZE demonstration
- AMAZE verification
- Summary

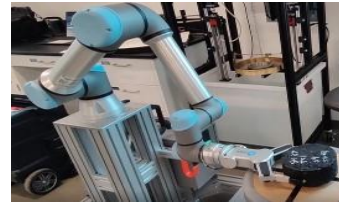
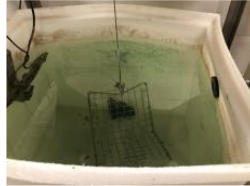


Key Message	Agenda
Interactive	This training includes five parts: <ul style="list-style-type: none">• Introduction.• AMAZE development.• AMAZE demonstration.• AMAZE verification.• Summary.
Notes	N/A

Introduction-Motivation



- Safety: Keep people safe
- Productivity
 - ▣ Improve productivity
- Accuracy/consistency
 - ▣ Improve accuracy by removing human errors



Key Message	Introduction
Interactive	In this section, we will discuss why automating lab tests is important in terms of safety, productivity, and accuracy/consistency.
Notes	N/A

Introduction-Motivation

□ Workforce:

- Lack of workforces
- Lack of workforce skills



□ Balanced mix design:

- Every step is critical to have a good performance pavement

Raw Materials

- Aggregates
- Asphalt Binder
- Recycled Material
- Rejuvenator/Other

Mix Design

- Batching
- Mixing
- Curing
- Compaction/Density
- Performance Tests

Trial Batch (JMF Approval)

- Plant Production
- Curing
- Ignition Oven Test
- Compaction/Density
- Performance Tests with Reheated Plant Mix

Production and Transport

- Plant Production
- Curing
- OC/OA
- Ignition Oven Test
- Compaction/Density
- Performance Tests
- Reference Testing with Reheated Plant Mix

Placement and Field Cores

- Field Compaction
- In-place Air Voids
- Field Cores at Different Times
- Performance Tests

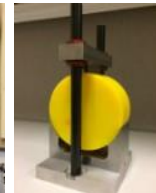


Key Message	Introduction
Interactive	In this section, we will discuss why automating lab tests is important in terms of workforce shortage and balanced mix design.
Notes	N/A

Introduction-Asphalt mixture properties



- Key asphalt mixture properties:
 - AASHTO T 166: Bulk specific gravity (air voids)
 - TxDOT Tex-226-F Indirect tensile strength test
 - TxDOT Tex-250-F: IDEAL cracking test (IDEAL-CT)
 - ASTM D8360: Ideal rutting test (Ideal-RT)



Key Message	Introduction
Interactive	<p>In this section, we will discuss four essential asphalt mixture properties:</p> <ol style="list-style-type: none"> 1. Bulk specific gravity (or air voids). 2. Indirect tensile strength (IDT). 3. Ideal cracking test (IDEAL-CT)—cracking tolerance index. 4. Ideal rutting test (IDEAL-RT)—rutting tolerance index.
Notes	N/A

Introduction-Objective



Objective

Present an asphalt mixture automated testing system with zero intervention (AMAZE) for Balanced mix design and quality acceptance

- Bulk specific gravity (air void) measurement unit
- Conditioning unit
- Robotic arm unit
- IDT/IDEAL-CT/RT loading unit
- Specimen trash unit



Key Message	Introduction
Interactive	This section will describe the objective of this training: present AMAZE for balanced mix design and quality acceptance. <ol style="list-style-type: none">1. Bulk specific gravity (air void) measurement unit.2. Conditioning unit.3. Robotic arm unit.4. IDT/IDEAL-CT/RT loading unit.5. Specimen trash unit.
Notes	N/A

AMAZE development



Laboratory **Manual** Operations



Key Message	AMAZE development
Interactive	This section will describe the current state of practice for the manual operation of each step of the testing process, from measuring air voids, to conditioning specimens, to conducting tests, to dumping broken specimens.
Notes	N/A

AMAZE development

□ Air voids measurement

Manual operation



Robot operation

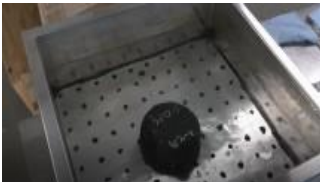


Key Message	AMAZE development
Interactive	This section will describe how the robotic arm works for measuring air voids.
Notes	N/A

AMAZE development

- Specimen conditioning

Manual operation



Robot operation



Key Message	AMAZE development
Interactive	This section will present the robotic arm loading the specimen to the conditioning unit.
Notes	N/A

AMAZE development

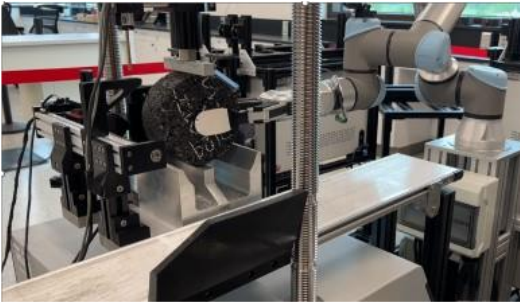


- Loading frame

Manual operation



Robot operation



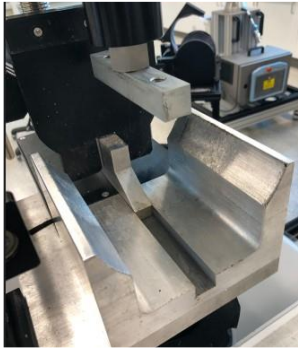
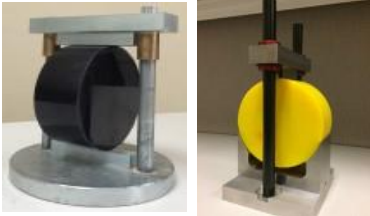
Key Message	AMAZE development
Interactive	This section will present the use of the robotic arm to load the specimen to the loading frame.
Notes	N/A

AMAZE development

- Loading frame-automated fixture exchange

Combined fixture with automatic switch

Manual switch between fixtures

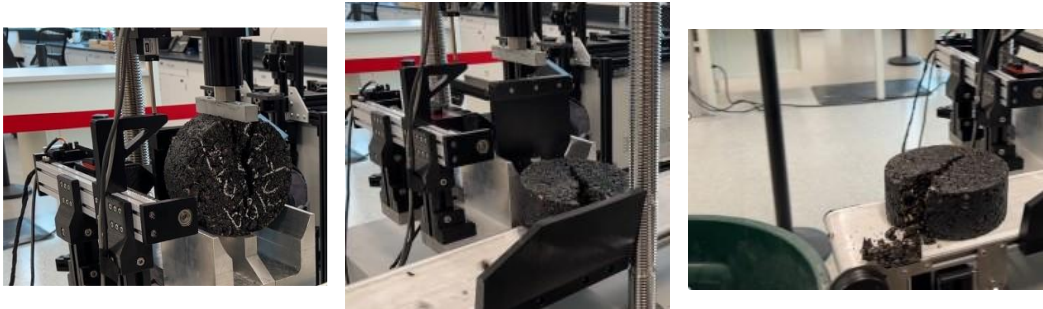


Key Message	AMAZE development
Interactive	This section will present how the combined fixture works to automatically exchange the CT and RT fixtures.
Notes	N/A

AMAZE development

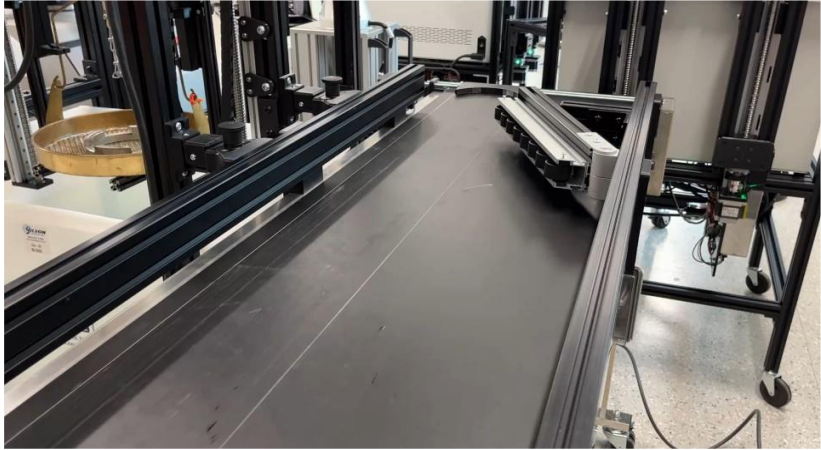
- Specimen dumping

Automatically catch, push, and dump



Key Message	AMAZE development
Interactive	This section will describe how to remove the tested (or broken) specimen out of the combined fixture and then dispose of it.
Notes	N/A

AMAZE demonstration

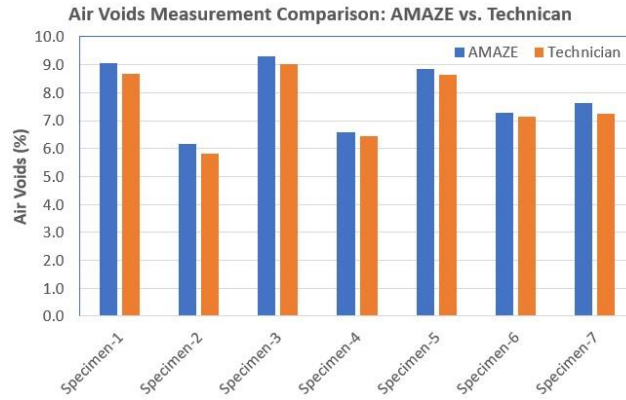


Key Message	AMAZE demonstration
Interactive	This section will present a 4-minute video demonstrating how AMAZE works in detail.
Notes	N/A

AMAZE verification



□ Air voids measurement

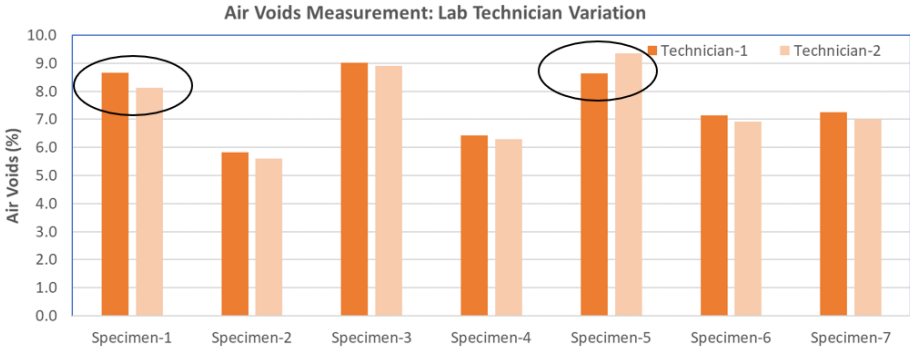


Key Message	AMAZE verification
Interactive	This section will compare the air voids of specimens measured by AMAZE and a lab technician. It is clear that the results are very close.
Notes	N/A

AMAZE verification



□ Variation of lab technicians



Key Message	AMAZE verification
Interactive	This section will present the air voids measurement from two different lab technicians. For Specimens 1 and 5, there are some differences between the lab technicians, although both technicians have more than 10 years of experience in performing air voids measurement.
Notes	N/A

AMAZE verification

□ Consistency of robot measurements

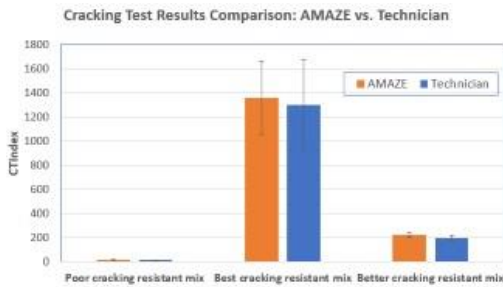


Key Message	AMAZE verification
Interactive	This section will present the consistency of the air voids measured by the robotic arm. For all seven specimens, the measured air voids are almost identical.
Notes	N/A

AMAZE verification



IDEAL-CT and RT



Key Message	AMAZE verification
Interactive	This section will present the comparison of the CT_{Index} and RT_{Index} between AMAZE and the lab technician. The test results are comparable, but AMAZE has slightly smaller variation in terms of standard deviation.
Notes	N/A

Summary



- AMAZE is a useful testing system to measure the four essential asphalt mixture properties.
- AMAZE is ready for implementation.
 - ▣ Pilot projects
 - ▣ More test units for regional labs.



Key Message	Summary
Interactive	This section will summarize the training.
Notes	N/A

SECTION III. STUDENT PARTICIPANT GUIDE

The student participant guide describes the functions of AMAZE and provides a step-by-step guide on how to use AMAZE.

SPACE REQUIREMENTS

AMAZE requires a minimum space of 12 ft × 12 ft. Figure 1 shows the top view of the system.



Figure 1. Top View of System

ELECTRICAL REQUIREMENTS

AMAZE requires two different power sources, one for the main system's components and the other for the central computer, as detailed below.

- System:
 - Power input requirements: 125V AC—50 amps, isolated circuit.
 - Receptable outlet: NEMA 14-50r.
- Central computer:
 - Power input requirements: 100–240V AC—1.8 amps.

SYSTEM DESCRIPTION

AMAZE is a cutting-edge solution designed to revolutionize the asphalt mixture testing process. The goal of the system is to increase consistency and accuracy of test results, eliminate human error, improve efficiency, and reduce testing times. AMAZE is engineered to automatically measure four essential asphalt mixture properties: bulk specific gravity (i.e., air voids with the condition of known rice value), cracking resistance, rutting resistance, and indirect tensile strength.

The system is comprised of six main units that are arranged tightly around a central robotic arm, a UR-5e robot with a gripper (see Figure 1). This robotic arm grabs an asphalt specimen and moves it through the various stages of the testing process to measure essential properties of asphalt mixtures.

AMAZE has multiple components that work together to perform the desired tests for asphalt specimens. The system is composed of six different units. Each unit within the AMAZE system is not only distinct in function but also designed for mobility, such that each unit can be moved for maintenance or transportation. This mobility feature is particularly beneficial for adapting the system layout to different operational environments or specific testing requirements. The subsequent subsections provide a detailed exposition of each unit, delineating the individual roles and functionalities within the AMAZE system.

Radio-Frequency Identification (RFID) Unit

The RFID system integrated into AMAZE serves as a pivotal component for enhancing sample identification, substantially diminishing the risk of conducting incorrect tests on given samples. This system leverages RFID technology to accurately ascertain the identity of each sample, thereby ensuring that the appropriate test is performed.

This RFID system is composed of two primary elements:

- **Desktop RFID Staging Unit (Figure 2):** This unit plays a crucial role in the initial stages of the testing process. It is utilized for individually registering each sample, a process that involves creating a testing profile file. This file is pivotal for the AMAZE system because it guides the subsequent testing procedures by providing detailed information about each sample.



Figure 2. Desktop RFID Staging Unit

- Sample RFID Reader (Figure 3): Positioned within the AMAZE system, this reader operates during the testing phase. Its function is to identify each sample as it is about to undergo testing. By reading the RFID tags attached to the samples, the reader ensures that each specimen is correctly identified, thus aligning the testing process with the information outlined in the testing profile file.



Figure 3. Sample RFID Reader

In essence, the RFID system in AMAZE enhances the testing accuracy by providing a reliable method of sample identification, which is essential in maintaining the integrity of the testing process and the validity of the test results.

Carousel Unit

The carousel unit in the AMAZE system is integral for feeding asphalt specimens into the testing process. It is designed to hold up to two samples across its three-tiered structure, with each sample position clearly numbered to prevent misplacement. Users are advised to load the samples sequentially without skipping any numbered spot, ensuring an orderly and efficient testing procedure.

This unit is directly docked to the air voids unit, facilitating a smooth transition of samples into the initial phase of testing. Its operation is driven by a powered rotary table, which accurately rotates the tiers to align the samples for pickup by the robotic arm. This precision in rotation is crucial for the consistent and reliable transfer of samples for testing. The overall functionality of the carousel unit, as shown in Figure 4, enhances the efficiency and accuracy of the AMAZE system's testing process.

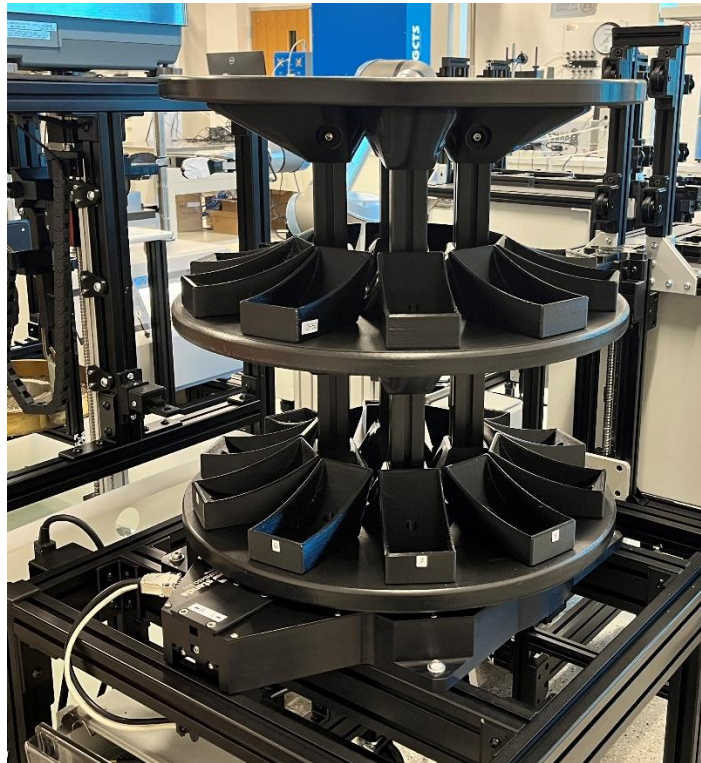


Figure 4. Carousel Unit

Air Voids Unit

The air voids unit is composed of two key components: weight measurement and saturated surface dry (SSD). The weight measurement component measures the dry weight of an asphalt specimen, the weight of the specimen submerged in the water, and the weight of the SSD of the specimen. The air voids unit is equipped with two linear actuators, which lower an asphalt specimen into the water and lift it out of the water. Figure 5 shows the weight measurement component of the air voids unit.

Another part of the air voids unit is the SSD component (see Figure 6). The major function of the SSD component is to dry the surface of an asphalt specimen with a dampened towel so that SSD is achieved.



Figure 5. Weight Measurement Component



Figure 6. Saturated Surface Dry Component

Specimen Conditioning Units

The AMAZE system includes two specimen conditioning units specifically designed to address the temperature sensitivity of asphalt mixtures. These units are integral for preparing test specimens for the indirect tension asphalt cracking test (IDEAL-CT) and IDEAL rutting test (IDEAL-RT). Although both units share identical designs, they are designated for different conditioning temperatures. The first unit conditions specimens at a standard room temperature of 25 °C (77 °F), suitable for the IDEAL-CT. In contrast, the second unit is tailored for the IDEAL-RT, conditioning specimens at a higher temperature of 50 °C (122 °F). Each conditioning unit possesses the capacity to accommodate up to eight specimens simultaneously, ensuring efficient and uniform conditioning for multiple samples. This feature is especially useful for handling bulk testing scenarios, enhancing productivity and consistency in test results. Figure 7 specifically showcases the specimen conditioning unit designated for either the IDEAL-CT or the IDEAL-RT.



Figure 7. Specimen Conditioning Unit for IDEAL-CT (or IDEAL-RT)

Specimen Storage Unit

In some cases, users may choose to simply measure air voids of an asphalt specimen and then store it for later use. The specimen storage unit shown in Figure 8 is designed to save and store the specimen. It is connected to the main body of the system via the docking system.



Figure 8. Specimen Storage Unit

Loading Frame Unit

The loading frame unit is engineered to perform three tests: IDEAL-CT, IDEAL-RT, and indirect tensile strength. At the heart of this unit is the Humboldt 5040 loader, which applies an axial compressive load to the specimens and records the time, load, and displacement data. Furthermore, this loading frame unit is enhanced with a conveyor belt, a two-in-one fixture, and a self-cleanup system to allow for automatically cleaning up the tested specimen. Figure 9 shows the loading frame unit.



Figure 9. Loading Frame Unit

Robot Arm Unit

The robotic arm unit is the central component within the AMAZE system. It transfers the asphalt specimens among different units during the testing process. It is equipped with a specialized gripper capable of holding the specimen in any orientation.

Furthermore, the robotic arm frame is seamlessly integrated into the AMAZE system's power infrastructure. It is directly connected to the system's power distribution panel, which encompasses essential electrical components such as breakers, surge protectors, and cables of the appropriate gauge to handle expected loads. This integration underscores the unit's reliability and safety during operation. Surrounding the frame of the robotic arm are five receptacles, each dedicated to different units of the AMAZE system. This strategic placement facilitates efficient power distribution and connectivity for the entire system. Figure 10 shows the robotic arm unit.



Figure 10. Robot Arm

Central Computer Unit

The central computer unit is the system's control center, coordinating the testing sequence, processing data from the machines, and sending the test results to the users. Figure 11 shows the central computer.



Figure 11. Central Computer Unit

SEVEN TESTING OPTIONS

AMAZE offers seven different testing options, giving users testing flexibility based on their needs. These seven testing options are described below.

- Option 1: Air Voids Only. When this option is chosen, AMAZE measures the bulk specific gravity of the specimen and then calculates its air voids. After the bulk specific gravity measurement is complete, the specimen is stored in the specimen storage unit. The robotic arm moves to the next task.
- Option 2: IDEAL-CT Only. If users want to skip the air voids measurement and directly perform the IDEAL-CT, they can choose this option. In this case, the robotic arm picks up the specimen and loads it into the loading frame unit for the IDEAL-CT testing. After testing is complete, the loading frame unit automatically pushes the broken specimen to a conveyor belt, transferring the specimen to a trash can.
- Option 3: Air Voids and IDEAL-CT with Specimen Conditioning. This option is designed for users who want to measure the specimen's air voids and condition the specimen in a water bath to the target temperature before running the IDEAL-CT.
- Option 4: Air Voids and IDEAL-RT with Specimen Conditioning. This option allows users to measure the specimen's air voids first and then condition the specimen in a water bath to the target temperature before running the IDEAL-RT. For all IDEAL-RT specimens, conditioning the specimens to the target testing temperature is required.
- Option 5: Air Voids and IDEAL-CT. This option is designed for scenarios where users want to measure the air voids of the specimen and then run the IDEAL-CT. This option provides users with the flexibility to skip the specimen conditioning stage.
- Option 6: IDEAL-CT with Specimen Conditioning. This option directly conditions the specimen in a water bath without performing the air voids measurement. After the specimen reaches its target testing temperature, the robotic arm picks it up, and then the IDEAL-CT is performed.
- Option 7: IDEAL-RT with Specimen Conditioning. This option directly conditions the specimen in a water bath without performing the air voids measurement. After the specimen reaches its target testing temperature, the robotic arm picks it up, and then the IDEAL-RT is performed.

PRE-TESTING PREPARATION

Prior to initiating tests with the AMAZE system, users must complete certain preparatory steps to ensure accurate and efficient testing. These steps are outlined below:

1. **Select Testing Mode:** Users must choose between two distinct operating modes.
 - a. **RFID Mode:** This mode is chosen when RFID is used for sample identification. The desktop RFID staging unit, as depicted in Figure 2, is utilized to create the testing profile file. In this mode, the sequence of sample placement in the testing carousel is not constrained by the order in the testing profile file, offering flexibility for the user.
 - b. **Non-RFID Mode:** This mode is comparatively simpler, requiring no additional tagging of the samples. The critical requirement in this mode is the alignment of the

sample order in the carousel with that in the testing profile file, ensuring consistency between the physical setup and the testing input.

2. **Prepare Specimen.** AMAZE can test either laboratory compacted specimens or field cores as long as they are 150 mm in diameter by 62 mm in height. For samples used in RFID mode, an RFID tag must be affixed to each sample. This is achieved using a thin layer of silicone, preferably a low-strength silicone, to secure the tag in place. It is imperative to allow the silicone to dry completely before proceeding with testing to ensure tag stability and integrity during the testing process. Figure 12 shows an RFID tag on an asphalt specimen.



Figure 12. RFID Tag on Asphalt Specimen

3. **Prepare Testing Profile File for AMAZE.** To initiate the testing process, it is imperative to create a testing profile file using the AMAZE registrar software specifically designed to guide users through the creation of a testing profile file. This step is mandatory for each test, regardless of the number of samples being evaluated—even for individual sample testing. Figure 13 shows the AMAZE registrar graphical user interface (GUI).

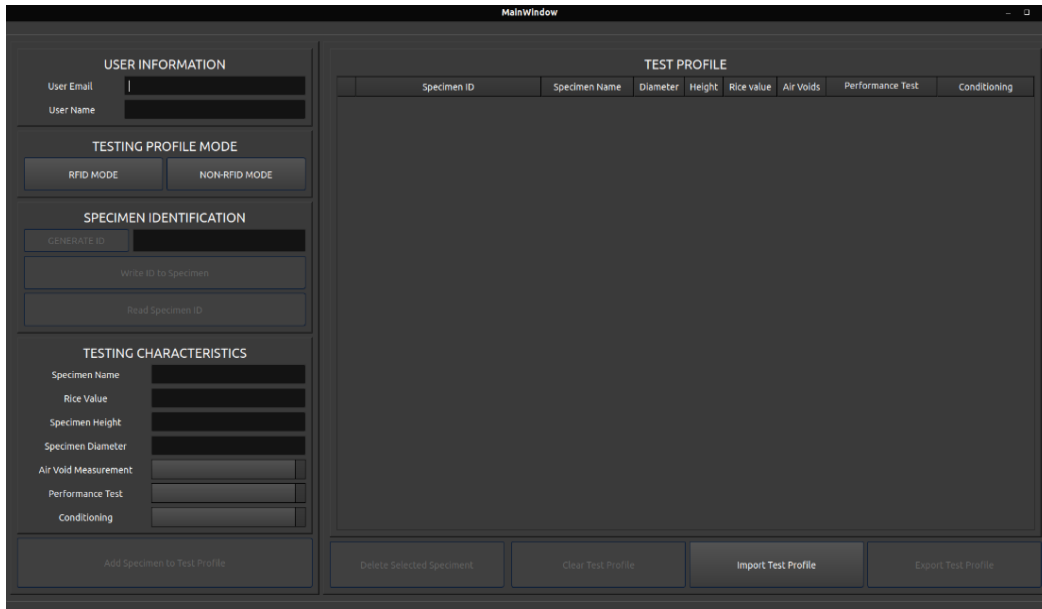


Figure 13. AMAZE Registrar Software

Upon opening the AMAZE registrar GUI, users should follow the subsequent steps to prepare a testing profile file:

- a. **User Information Entry:** Begin by entering the user’s information into the system. This step is crucial for maintaining a record of who is conducting the test.
- b. **Testing Profile Mode Selection:** Choose the appropriate testing profile mode from the available options.
- c. **Specimen Information Input:** Input detailed information about each specimen, including its name, rice value, and physical dimensions like height and diameter. Accurate entry of these data is essential for the precise analysis of the specimen.
- d. **Test Combination Selection:** For each specimen, select the combination of tests to be conducted. This step is crucial for tailoring the testing procedure to the specific requirements of the specimen.
- e. **Addition of Specimen to Test Profile:** After inputting all necessary information for a specimen, add it to the test profile file. This action registers the specimen for the upcoming test.
- f. **Repeating for Additional Samples:** Repeat steps c through e for each additional sample that needs to be tested. Ensure that each specimen is accurately registered with its respective information.
- g. **Exporting of the Test Profile:** Once all specimens are registered and the test profile is complete, use the “Export Test Profile” button to save the file to a desired location on the computer. This exported file will be used by the AMAZE testing software to conduct the tests.

Following these steps ensures that each specimen is accurately recorded and the testing parameters are set correctly in the AMAZE system. The exported test profile file is a critical component for the AMAZE testing software to perform the tests as per the specified requirements.

4. **Prepare Robotic Arm.** The robotic arm is used in AMAZE to transfer asphalt specimens among different testing units. To prepare the robotic arm for testing operations, follow these steps:
 - a. Turn on the robot by pressing the power button on the robot's tablet, as shown in Figure 14.



Figure 14. Robot Arm Power Button

- b. Press the POWER OFF button located on the bottom left of the robot's tablet to start the initialization process, as shown in Figure 15.

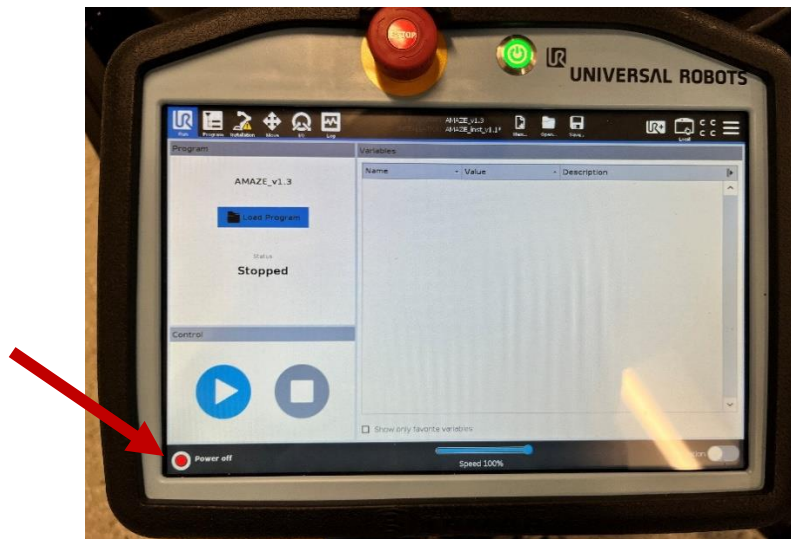


Figure 15. Starting Robot Initiation

c. Press the ON button, as shown in Figure 16.

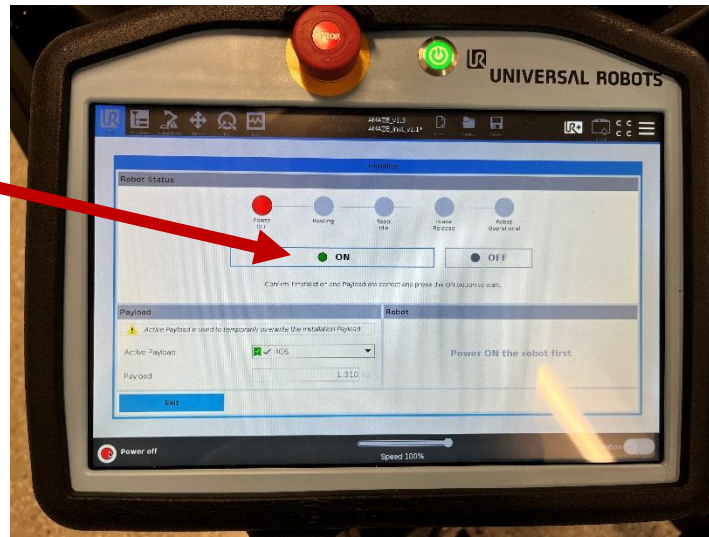


Figure 16. Turning On Robot

d. After the robot boots up, press the START button, as shown in Figure 17.

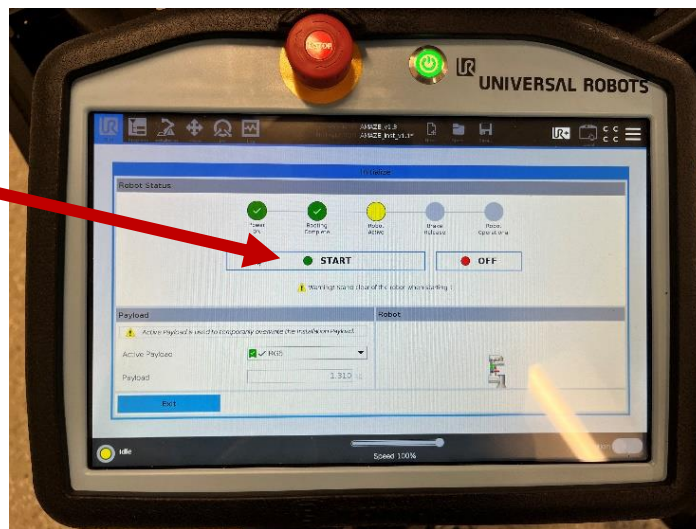
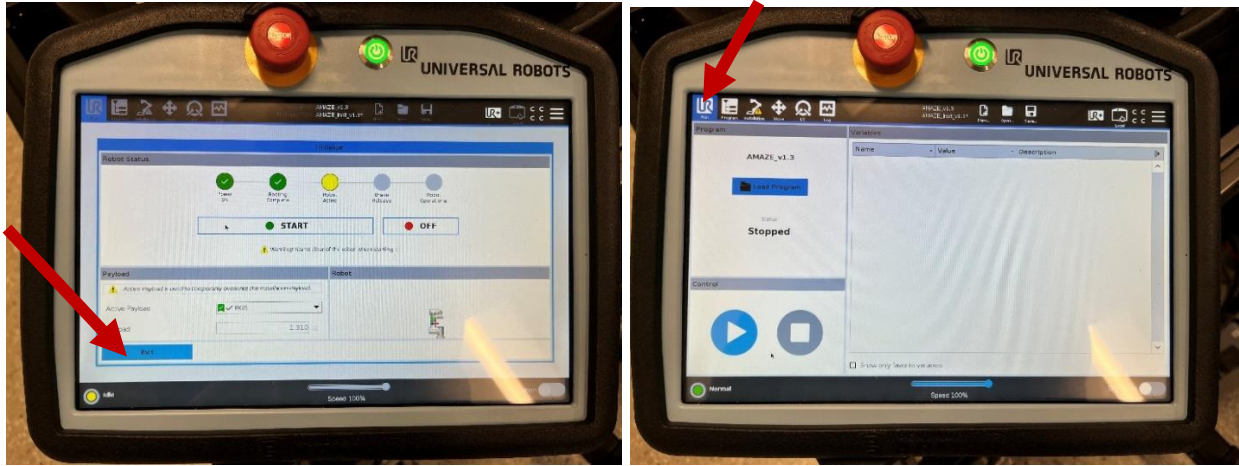


Figure 17. Starting Robot

- e. Exit the initialize screen and go to the RUN tab on the robot's tablet, as shown in Figure 18.



a. Exit button

b. Run tab

Figure 18. Exit Button and Run Tab

- f. Press the PLAY button (Figure 19), and the robot program should begin playing. Figure 20 shows the RUN tab when the program is playing. When needed, users can manually stop the robot's program by pressing the STOP button (Figure 21).

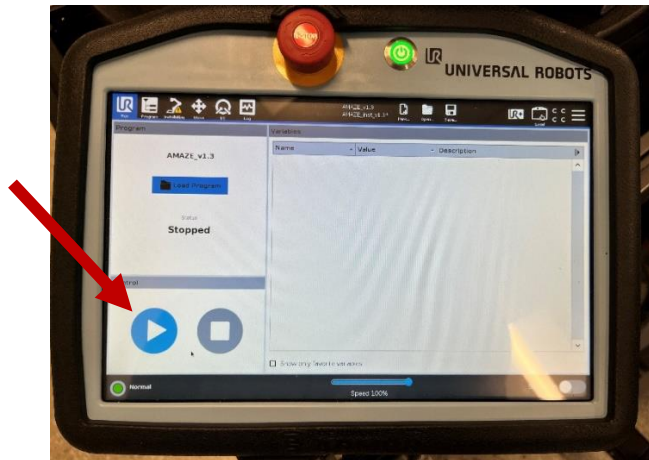


Figure 19. Play Button

TESTING OPERATION PROCEDURE

After completing the pre-testing preparation, proceed to the testing phase with the following steps.

1. **Launch the AMAZE Testing Software.** Double-click the AMAZE icon (Figure 22) located on the laptop desktop to launch the AMAZE testing software. Once launched, the screen shown in Figure 23 will be displayed. This GUI is instrumental in controlling individual machines, initiating and stopping tests, and displaying test results.

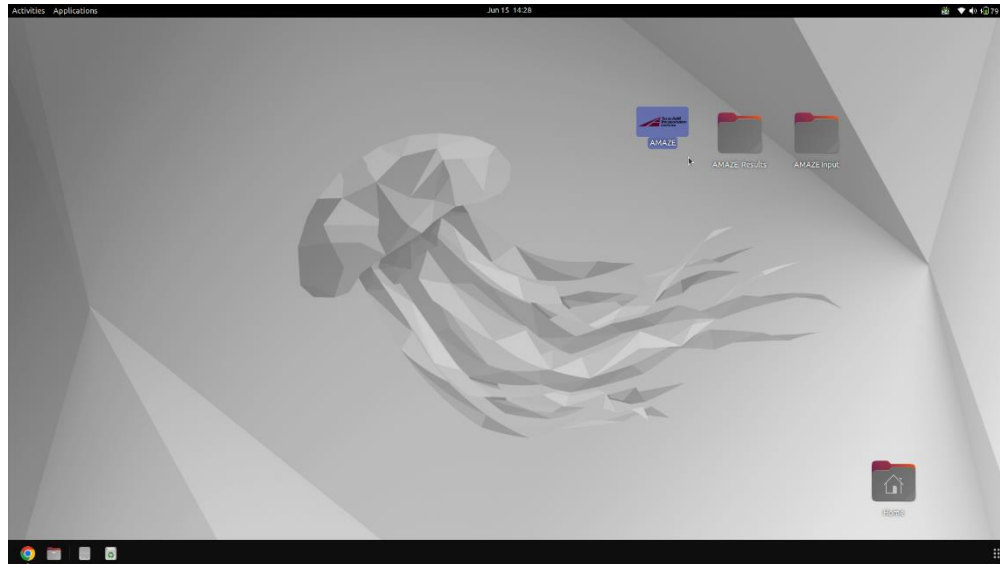


Figure 22. AMAZE Icon

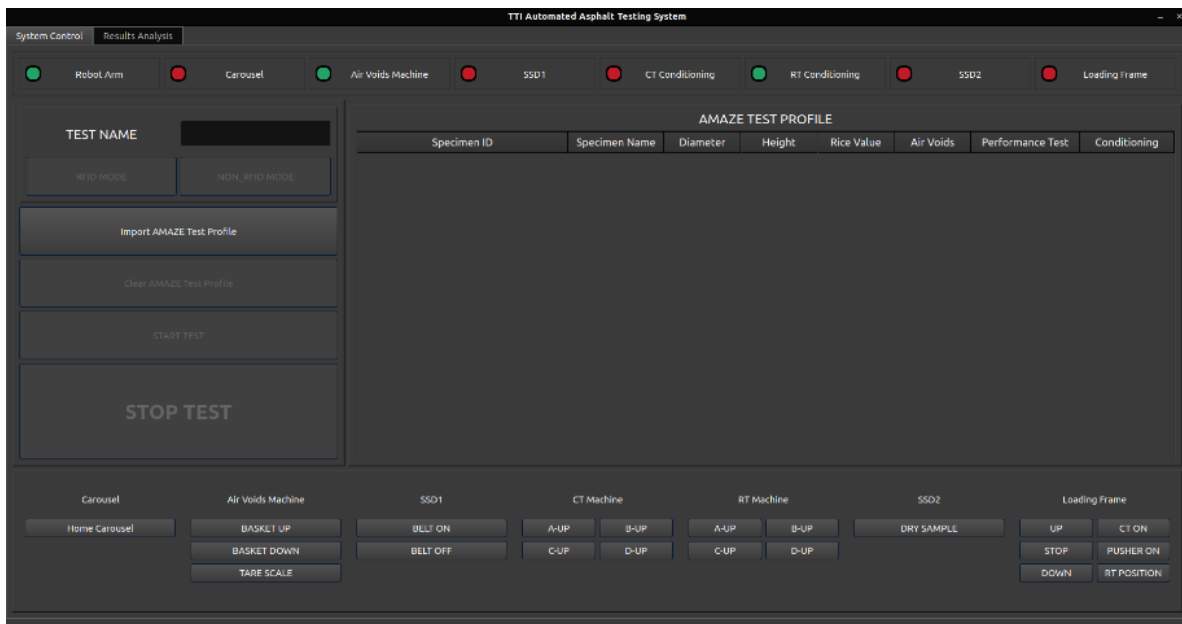


Figure 23. AMAZE System Control Screen

2. **Import the AMAZE Test Profile File.** Within the GUI, click on the “Import AMAZE Test Profile” button. Select the test profile file previously created using the AMAZE registrar software. This file contains all the necessary configurations and specimen details for the test. Figure 24 shows the testing profile after importing the file.

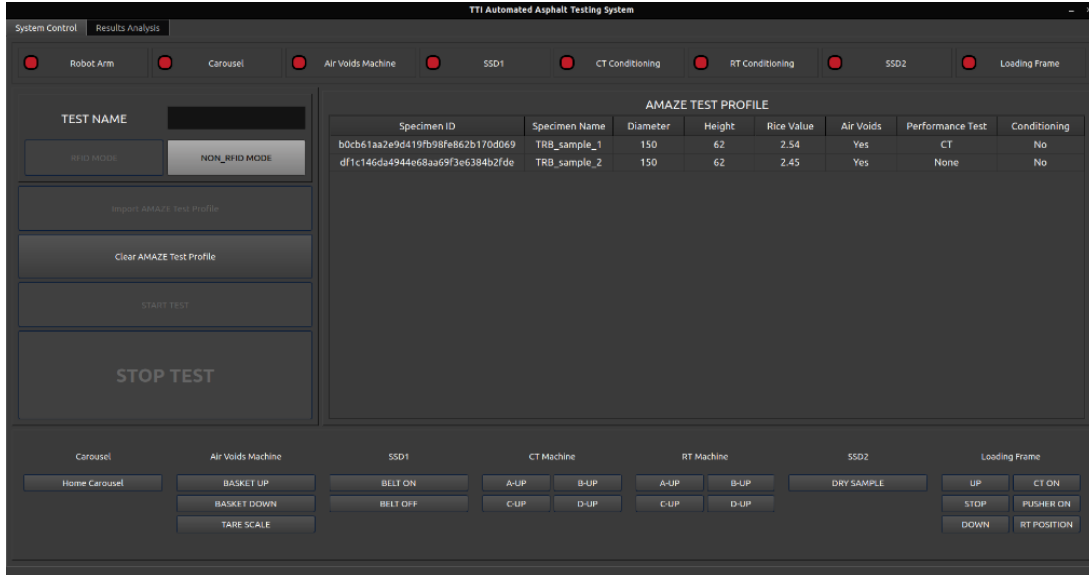


Figure 24. Importing Test Profile

3. **Assign a Name to the Test.** Assign a unique and identifiable name to the test. This step is crucial for record-keeping and future reference. Figure 25 shows the GUI after adding a test name.

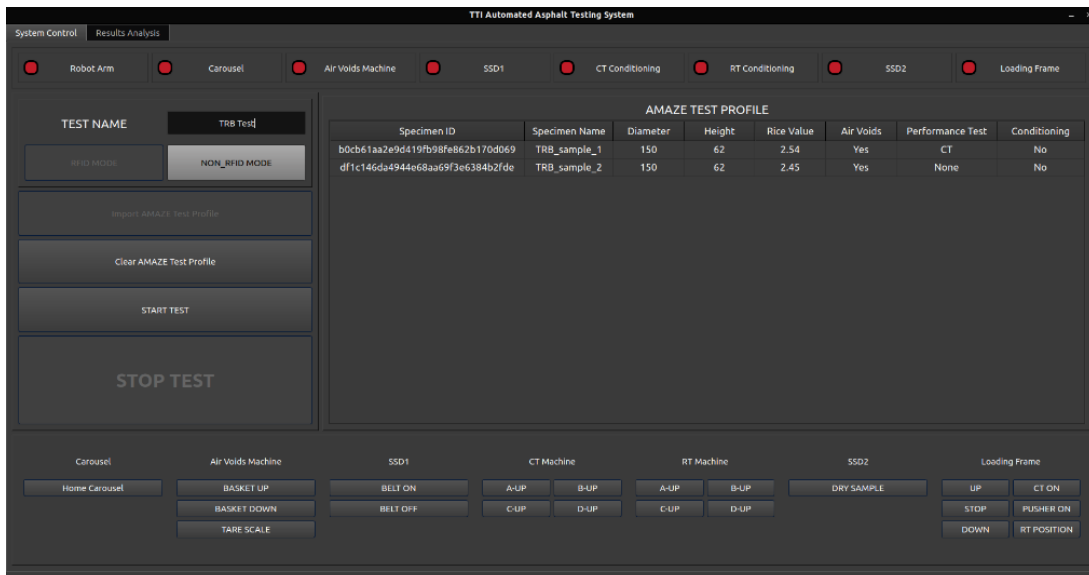


Figure 25. Screen for Assigning a Test Name

4. **Verify Machine Status.** Ensure that all the machine status LEDs displayed at the top of the GUI are green. This indicates that each machine is operational and ready for testing. If any LED is red, indicating an issue, reboot the corresponding machine and wait until the LED turns green, signaling readiness. Figure 26 shows all the machine status LEDs as green.

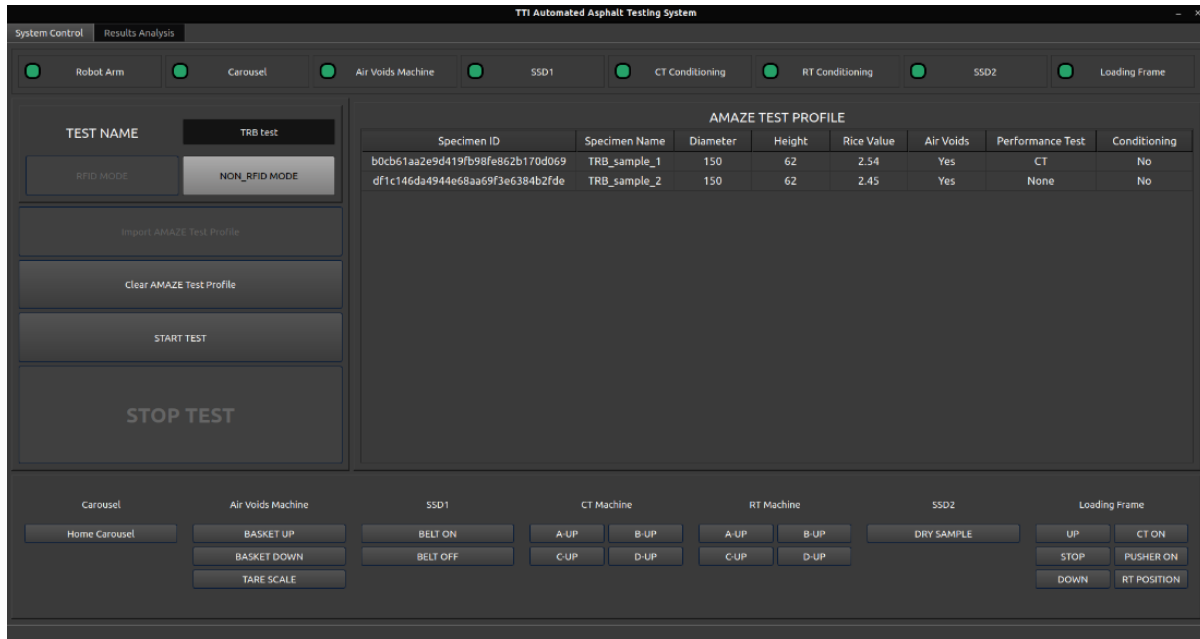


Figure 26. Screen of Machine Status

5. **Start Test.** Once all LEDs are green, a test name is assigned, and the test profile file is successfully loaded, the START TEST button will become active. Press this button to commence the testing process.
6. **Present Test Results.** Once the testing process is initiated using the AMAZE testing software, the system will automatically conduct tests on each specimen. As each specimen is tested, its results are immediately recorded and displayed in the results table, which can be found under the Results Analysis tab. Figure 27 shows the tab. In addition to the results being displayed on the Results Analysis tab, all of the raw data are saved to a folder named Result Folder under the AMAZE folder.

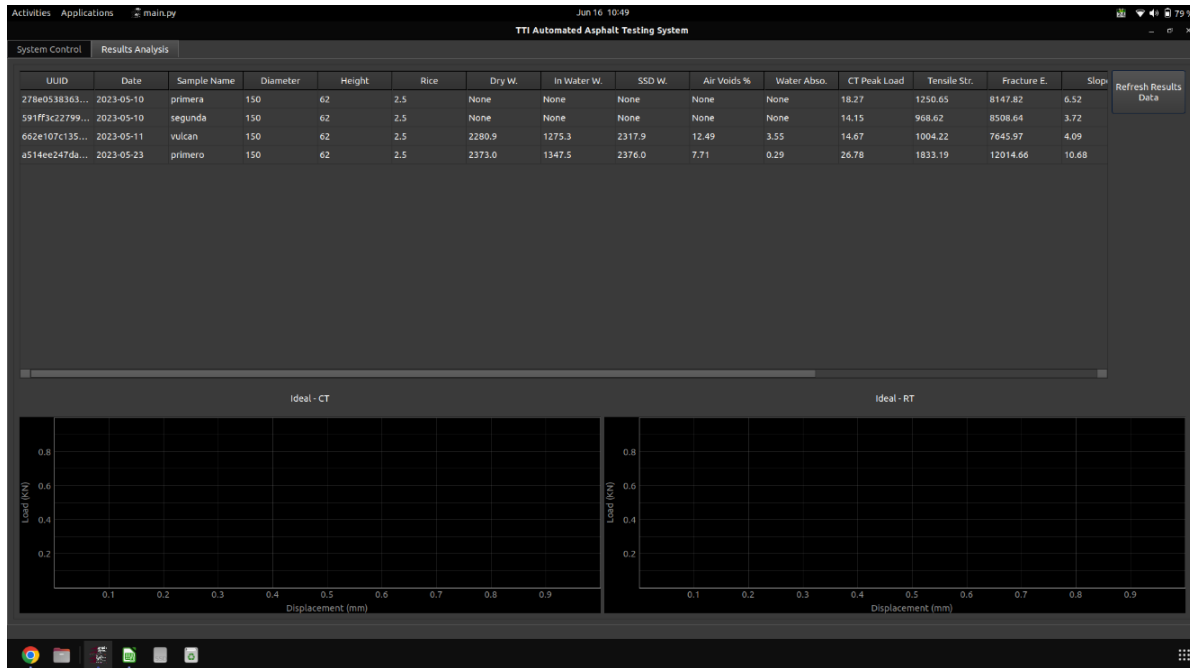


Figure 27. Presentation of Test Results

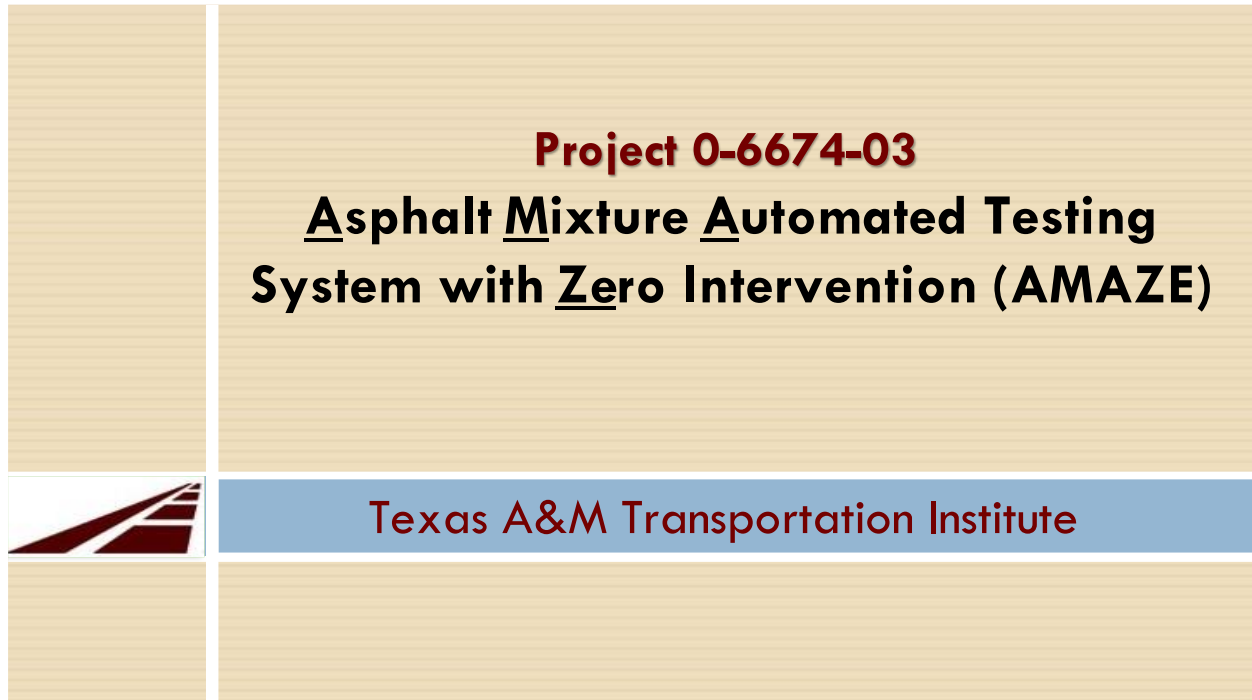
POST-TESTING OPERATION

Once all the specimens are tested, users should receive a notification on the screen that the test is complete. Following are the post-testing operation steps to then take:

1. Load a new testing profile and assign a new test name if starting another test.
2. If another test does not need to be started, complete the following steps for the correct turn-off procedure.
 - a. Close the AMAZE application.
 - b. Turn off all the machines via their ON/OFF switch.
 - c. Clean up the specimen trash and the specimen storage unit.
 - d. Turn off the robotic arm.
 - e. Save results on a removable flash drive.

SECTION IV. TRAINING PRESENTATION

This training presentation includes the reasons for developing AMAZE, the function of AMAZE, and the verification of AMAZE.



Project 0-6674-03
**Asphalt Mixture Automated Testing
System with Zero Intervention (AMAZE)**

Texas A&M Transportation Institute

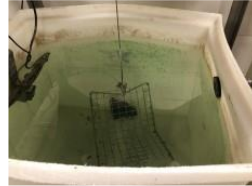
Presentation outline

- Introduction
 - Motivation
 - Objective
- AMAZE development
- AMAZE demonstration
- AMAZE verification
- Summary



Introduction-Motivation

- Safety: Keep people safe
- Productivity
 - ▣ Improve productivity
- Accuracy/consistency
 - ▣ Improve accuracy by removing human errors



Introduction-Motivation

- Workforce:
 - ▣ Lack of workforces
 - ▣ Lack of workforce skills
- Balanced mix design:
 - ▣ Every step is critical to have a good performance pavement



Raw Materials

- Aggregates
- Asphalt Binder
- Recycled Material
- Rejuvenator/Other

Mix Design

- Batching
- Mixing
- Curing
- Compaction/Density
- Performance Tests

Trial Batch (JMF Approval)

- Plant Production
- Curing
- Ignition Oven Test
- Compaction/Density
- Performance Tests with Subheated Plant Mix

Production and Transport

- Plant Production
- Curing
- OC/OA
- Ignition Oven Test
- Compaction/Density
- Performance Tests
- Reference Testing with Reheated Plant Mix

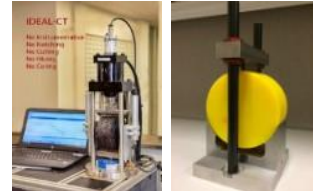
Placement and Field Cores

- Field Compaction
- In-place Air Voids
- Field Cores at Different Times
- Performance Tests



Introduction-Asphalt mixture properties

- Key asphalt mixture properties:
 - AASHTO T 166: Bulk specific gravity (air voids)
 - TxDOT Tex-226-F Indirect tensile strength test
 - TxDOT Tex-250-F: IDEAL cracking test (IDEAL-CT)
 - ASTM D8360: Ideal rutting test (Ideal-RT)



Introduction-Objective

- Objective
 - Present an asphalt mixture automated testing system with zero intervention (AMAZE) for Balanced mix design and quality acceptance
 - Bulk specific gravity (air void) measurement unit
 - Conditioning unit
 - Robotic arm unit
 - IDT/IDEAL -CT/RT loading unit
 - Specimen trash unit



AMAZE development



Laboratory Manual Operations



AMAZE development



□ Air voids measurement

Manual operation



Robot operation

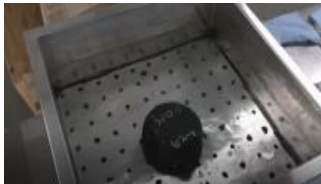


AMAZE development

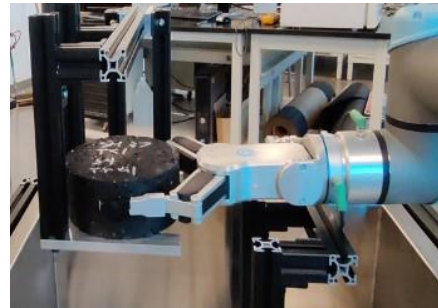


□ Specimen conditioning

Manual operation



Robot operation



AMAZE development



□ Loading frame

Manual operation



Robot operation



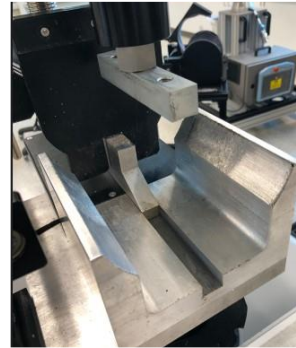
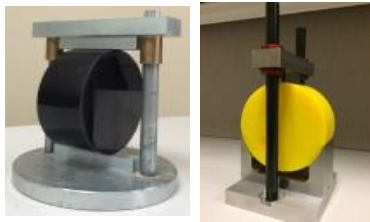
AMAZE development



- Loading frame-automated fixture exchange

Combined fixture with automatic switch

Manual switch between fixtures

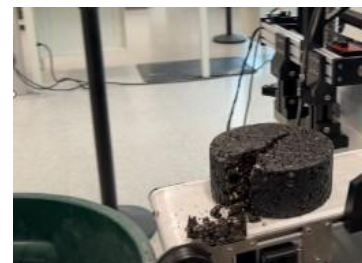
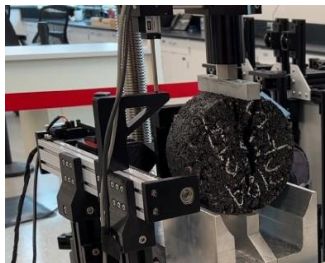


AMAZE development

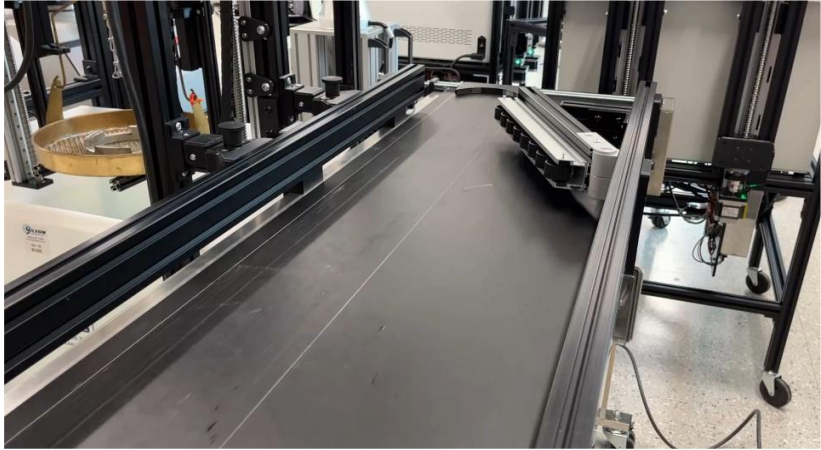


- Specimen dumping

Automatically catch, push, and dump

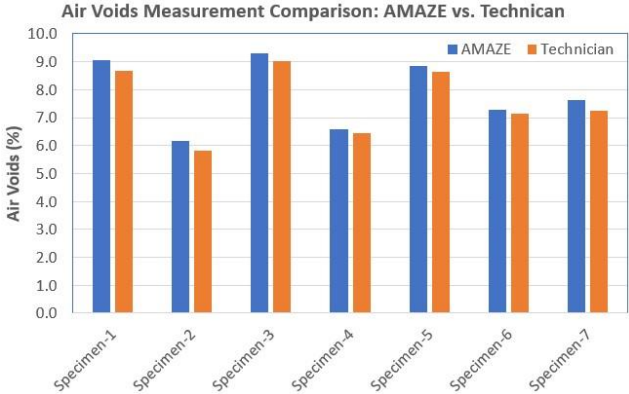


AMAZE demonstration



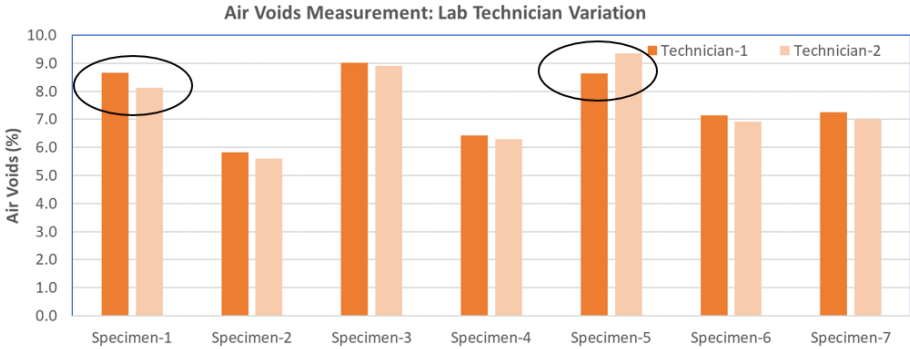
AMAZE verification

- Air voids measurement



AMAZE verification

Variation of lab technicians



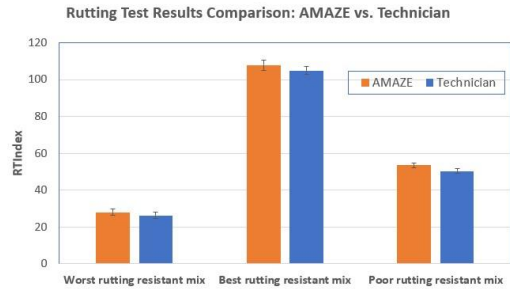
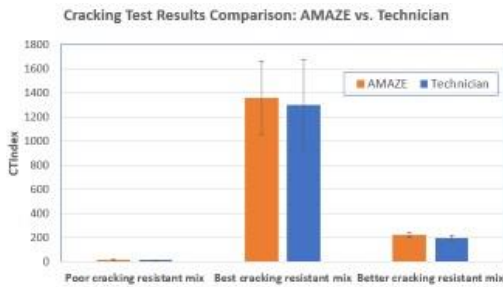
AMAZE verification

Consistency of robot measurements



AMAZE verification

IDEAL-CT and RT



Summary

- AMAZE is a useful testing system to measure the four essential asphalt mixture properties.
- AMAZE is ready for implementation.
 - Pilot projects
 - More test units for regional labs.



